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## ARTICLE I.

*Farther Experiments and Observations on the Affections and Properties of Light.*
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[Concluded from Page 155 of the present Volume.]

*Observation 5.*

THE direct light falling on the speculum, and part of the reflected light on the horizontal white stage of a very accurate micrometer, I measured the breadth of the fringes, spots, &c. These, with the distance of the speculum from the window and micrometer, and the size of the sun's image, are set down in the following table, all reduced to inches and decimals.

| | Inches. Parts. |
|---|---|
| Distance of the speculum from the hole in the window shut - - | 24. |
| Distance of the speculum from the stage of the micrometer - - | 18. |
| Transverse axis of the sun's image - - - - | 2.6 |
| Conjugate axis of the sun's image - - - - | 1.4 |
| Length of the oblong dark spot - - - - | .4 |
| Breadth of the oblong dark spot - - - - | .0074 |
| Breadth of its first fringe - - - - | .0022 |
| Elliptic spot's transverse axis - - - | .0016 |
| ——— conjugate axis - - - - | .0068 |
| Breadth of its first fringe - - - | .0034 |
| Transverse axis of a larger elliptic spot - - - | .013 |
| Conjugate axis of the same spot - - - | .0076 |

In

In the image where theſe meaſures were taken, there were ſeven other elliptic ſpots, a little leſs and nearly equal; all the others were much ſmaller and more confuſed.

*Obſervation* 6. On viewing the ſurface of the ſpeculum attentively in that place whence the rays formed the oblong and firſt mentioned elliptic ſpots, I ſaw a dark but very thin long ſcratch, and a dark dent, ſimilar in ſhape to the dark ſpaces on the image; the dark ſpot meaſured leſs than $\frac{1}{250}$ of an inch; which makes its whole ſurface to the whole poliſhed ſurface, as 1 to 34225, ſuppoſing the former circular or nearly ſo. All theſe meaſures will be found to agree very well, for their ſmallneſs and delicacy: thus, the ratio laſt mentioned is nearly the ſame which we obtain by comparing the image and the ſpot: the like may be ſaid of the two ſpots mentioned in the table, i. e. their axes are proportional. I now could produce what ſpots I pleaſed, by gently ſcratching the ſpeculum, or by making lines, dots, &c. with ink, and allowing it to dry; for theſe laſt formed convex fibres, which produced coloured fringes as well as the concavities, agreeably to what was deduced *a priori*.

*Obſervation* 7. The whole appearance which I have been deſcribing bore ſuch a cloſe and complete reſemblance to the fringes made round the ſhadows of bodies, that the identity of the cauſe in both caſes could not be doubted. In order, however, to ſhew it ſtill further, I meaſured the breadths of two contiguous fringes in ſeveral different ſets: the meaſurements agreed very well, and gave the breadth of the firſt fringe .0056, and of the ſecond .0034; or of the firſt .0066, and of the ſecond .0034. The ratio of the breadths by the firſt is 28 to 17; by the ſecond, 30 to 17; of which the medium is 29 to 17: and this is preciſely the ratio of the two innermoſt fringes made by a hair, according to Sir Iſaac Newton's meaſurement; the firſt being, according to him, $\frac{1}{170}$ of an inch; the ſecond, $\frac{1}{290}$ of an inch *. Farther, the two innermoſt rings made by plates have their diameters (not breadths) in the ratio of $1\frac{11}{16}$ to $2\frac{3}{8}$ †, and the diſtance between the middle of the innermoſt fringes (made by a hair), on either ſide the ſhadow, is to the ſame diſtance in the ſecond fringes as $\frac{1}{38}$ to $\frac{2}{47}$; therefore, the diameters of the two firſt rings made by the ſpecks in the ſpeculum, are as $\frac{209}{663}$ to $\frac{627}{1363}$; which ratio differs exceedingly little from that of $1\frac{11}{16}$ to $2\frac{3}{8}$, the ratio of the diameters of rings made by plates, either thoſe called by Newton thick, or thoſe which he names thin: for ſuppoſe this difference nothing, $2\frac{3}{8} \times \frac{209}{663} = 1\frac{11}{16} \times \frac{627}{1363}$; and the difference between theſe two products (now ſtated equal) is not much above $\frac{8}{9}$ in reality.

*Obſervation* 8. The laſt thing worth mentioning in theſe phenomena was this: I viewed the fringes through a priſm, holding the refracting angle upwards, and the axis parallel to that of the dark ſpace; then moving it till the objects ceaſed deſcending, I ſaw in that poſture the fringes much more diſtinct and numerous; for I could now ſee five with eaſe, and ſeveral more leſs diſtinctly. This led me to try more minutely the truth of the 5th propoſition, with reſpect to the number of the fringes ſurrounding the ſhadows of bodies in direct light. Having produced a bright ſet of theſe by a blackened pin $\frac{1}{25}$ of an inch in diameter, I viewed them through a well made priſm, whoſe refracting angle was only 30°, and held this angle upwards, when the fringes were on the ſide of the ſhadow oppoſite to me. I then moved the priſm round on its axis; and when it was in the poſture between the aſcent and deſcent of the objects, I was much pleaſed to ſee five fringes plainly, and a great number beyond, decreaſing in ſize and brightneſs till they became too ſmall and confuſed for

* Optics, book iii. obſ. 3.

† Book ii. parts 1 and 4.



ſight.

ſight. In like manner, thoſe formed by a double flexion of two bodies, and thoſe made out of homogeneal light, were ſeen to a much greater number when carefully viewed through the priſm. And this experiment I alſo tried with all the ſpecies of fringes by flexion which I could think of.

*Obſervation* 9. The ſame appearances which were occaſioned by the metal ſpeculum, might be naturally expected to appear when a glaſs one was uſed. But I alſo found the like rings or fringes of colours and ſpots in the image beyond the focus of a lens; nor was a very excellent one belonging to a Dollond's teleſcope free from them. The rings with their dark intervals reſembled thoſe floating ſpecks ſo often obſerved on the ſurface of the eye, and called "muſcæ volitantes," only that the muſcæ are tranſparent in the middle, becauſe formed by drops of humor: they will, however, be found to be compaſſed by rings of faint colours, which will become exceedingly vivid if the eyes be ſhut and ſlowly opened in the ſun's light, ſo that the humor may be collected; they alſo appear by reflexion, mixed with the colours deſcribed in Phil. Tranſ. for 1796, p. 268, (or Philoſ. Journal I. 593.)

*Obſervation* 10. The ſun ſhining ſtrongly on the concave metal ſpeculum, placed at ſuch a diſtance from the hole in the window that it was wholly covered with the light; upon inclining it a little, the image on the chart was bordered on the inſide with three fringes ſimilar to thoſe already deſcribed: on increaſing the inclination theſe were diſtended, becoming very bright and beautiful: when the inclination was great, and when it was ſtill increaſed, another ſet of colours emerged from the ſide next the ſpeculum, and was concave to that ſide. Here I ſtopped the motion, and the image on both ſides the focus had three ſets of fringes, and four fringes in each ſet; but when viewed through a priſm (as before deſcribed), the numbers greatly increaſed, both the fringes and the dark intervals decreaſing regularly. The appearance to the naked eye is repreſented in fig. 6, plate VII. where A D C being the image, A and C are the ſets of fringes at the edges, and B the third ſet, there being none at E and D the ſides, ſince the light which illuminates theſe quarters comes not from the edges of the ſpeculum in ſo great inclinations. I now viewed the ſurface of the ſpeculum, and ſaw it in the place anſwering to B in the image, covered with fringes exactly correſponding with thoſe at B; and on changing the figure of that part of the ſpeculum's edge between them and the ſun, the fringes likewiſe had their figure altered in the very ſame way. On moving the ſpeculum farther round, B came nearer to A in the image, according as the fringes on the ſpeculum receded from that ſide which formed them; and before they vaniſhed alike from the ſpeculum and image, they mixed with the colours at A in the image, and formed in their motion a variety of new and beautiful compound colours: among theſe I particularly remarked a brown chocolate colour, and various other ſhades and tinges of brown and purple. Juſt before the fringes at B appeared, the ſpace between A and C was filled with colours by reflexion, totally different in appearance from the fringes; but I could not examine them ſo minutely as I wiſhed in this broad image. I therefore made the following experiment:

*Obſervation* 11. At the hole in the window-ſhut I held the ſpeculum, and moved it to ſuch an inclination that the colours by reflexion might be formed in the image: they were much brighter and far more diſtended than the fringes, and were in every reſpect like the images by reflexion in the common way, only that the colours were a little better and more regular. They were alſo ſeen on the ſpeculum, as the third ſet of fringes had before been

been in Obſ. 10; but by letting the rays fall on the half next the chart, and inclining that half very much, I could produce them, though leſs diſtinctly, by a ſingle reflexion. I now held a plain metal ſpeculum, ſo that the rays might be reflected to form a white image on a chart. On inclining the ſpeculum much, I ſaw the image turn red at the edge; it then became a little diſtended; and laſtly, fringes emerged from it well coloured, and in regular order, with their dark intervals. This may eaſily be tried by candle-light with a piece of looking-glaſs; and thoſe who without much trouble would ſatisfy themſelves of the truth of the whole experiment contained in this and the laſt obſervation, may eaſily do it in this way with a concave ſpeculum; but the beauty of the appearance is hereby quite impaired. After this detail it is almoſt ſuperfluous to add, that the fringes at B, fig. 6, are formed by deflexion from the edge of the ſpeculum next the ſun, and then falling on it are reflected to the chart; that the images by reflexion are either formed by the light being decompounded at its firſt reflexion, and then undergoing a ſecond, or, in other inſtances, without this ſecond reflexion; and that the other fringes are produced exactly as deſcribed above, from the neceſſary conſequences of the theory. I ſhall only add, that nothing could have been more pleaſing to me than the ſucceſs of this experiment; not only becauſe in itſelf it was really beautiful from its variety, but alſo becauſe it was the moſt peremptory confirmation of what followed from the theory *a priori*, and in that point where the ſingularity of its conſequences moſt inclined me to doubt its truth.

Let us now attend to ſeveral concluſions to which the foregoing obſervations lead, independently of the propoſitions (viz. the five firſt) which they were made to examine.

I. We muſt be immediately ſtruck with the extreme reſemblance between the rings ſurrounding the black ſpots on the image made by an ill-poliſhed ſpeculum, and thoſe produced by thin plates obſerved by Newton; but perhaps the reſemblance is ſtill more conſpicuous in the colours ſurrounding the image made by any ſpeculum whatever, and fully deſcribed in Obſ. 10 and 11. The only difference in the circumſtances is now to be reconciled. The rings ſurrounding the black ſpot on the top of a bubble of water, and thoſe alſo ſurrounding the ſpot between two object-glaſſes*, have dark intervals (exactly like thoſe rings I have juſt now deſcribed, and the fringes ſurrounding the ſhadows of bodies); but theſe intervals tranſmit other fringes of the ſame nature, though with colours in the reverſe order; from which Sir Iſaac Newton juſtly inferred, that at one thickneſs of a plate the rays were tranſmitted in rings, and at another reflected in like rings. Now it is evident, that neither reflexibility nor refrangibility will account for either ſort of rings; becauſe the plate is far too thin for ſeparating the rays by the latter, and becauſe the colours are in the wrong order for the former; and alſo becauſe the whole appearance is totally unlike any that refrangibility and reflexibility ever produce. To ſay that they are formed by the thickneſs of the plates, is not explaining the thing at all. It is demanded, in what way? And indeed we ſee the like dark intervals and the ſame fringes formed at a diſtance from bodies by flexion, where there is no plate through which the rays paſs. The ſtate of the caſe then ſeems to be this: "When "a phenomenon is produced in a particular combination of circumſtances, and the ſame "phenomenon is alſo produced in another combination, where ſome of the circumſtances "before preſent are wanting; we are entitled to conclude, that the latter is the moſt gene-

* Optics, book ii. p. 1.

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" ral caſe, and muſt try to reſolve the other into it." In the firſt place, the order of the colours in the Newtonian rings is juſt ſuch as flexion would produce; that is, thoſe which are tranſmitted have the red innermoſt, thoſe which are reflected have the red outermoſt: the former are the colours arranged as they would be by inflexion, the latter as they would be by deflexion; and here by outermoſt and innermoſt muſt be underſtood relative poſition only, or poſition with reſpect to the thickneſs of the plate, not of the central ſpot. Secondly, the thinneſt plate makes the broadeſt ring (the diameter of the rings being in the inverſe ſubduplicate ratio of the plate's thickneſs): juſt ſo is it with fringes by flexion; nearer the body of the fringes are broadeſt, and their diameters increaſe in the ſame ratio with the diameters of the rings by plates whoſe thickneſs is uniform; each diſtance from the bending body therefore correſponds with a ring or fringe of a particular breadth, and the alternate diſtances correſpond with the dark intervals. The queſtion then is, what becomes of the light which falls on or paſſes at theſe alternate diſtances? In the caſe of thin plates, this light is tranſmitted in other rings: we ſhould therefore be led to think, that in the caſe of the light paſſing by bodies, it ſhould be at one diſtance inflected, and at another deflected: and in fact the phenomena agree with this; for fringes are formed by inflexion within the ſhadows of bodies; they are ſeparated by dark intervals; the fringes and the intervals without the ſhadow decreaſe in breadth according to the ſame law, ſo that the fringes and intervals within the ſhadow correſpond with the intervals and fringes without reſpectively. Nor will this explanation at all affect the theory formerly laid down; it will only (if found conſiſtent with farther induction) change the definite ſpheres of inflexion and deflexion into alternate ſpheres. At any rate, the facts here being the ſame with thoſe deſcribed by Newton, but in different circumſtances, teach us to reconcile the difference, which we have attempted to do, as far as is conſiſtent with ſtrictneſs; and what we have ſeen not only entitles us to conclude that the cauſe is the ſame, but alſo inclines us to look for farther light concerning that cauſe's general operation: and I truſt ſome experiments which I have planned, with an inſtrument contrived for the purpoſe of inveſtigating the ratio of the bending power to the diſtances at which it acts, will finally ſettle this point.

II. Another concluſion follows from the experiments now related, viz. that we ſee the great importance of having ſpecula for reflectors delicately poliſhed, not only becauſe the more dark imperfections there are on the ſurface the more light is loſt, and the more colours are produced by flexion (theſe colours would be moſtly mixed, and form white in the focus), but alſo becauſe the ſmalleſt ſcratches or hairs being poliſhed produce colours by reflexion, and theſe diverging irregularly from the point of incidence are never collected into a focus, but tend to confuſe the image. Indeed it is wonderful that reflectors do not ſuffer more from this cauſe, conſidering the almoſt impoſſibility of avoiding the hairs we ſpeak of: however, that they do actually ſuffer is proved by experience. I have tried ſeveral ſpecula from reflecting teleſcopes, and found that though they performed very well from having a good figure, yet from the focus (when they were held in the ſun's light) ſeveral ſtreaks diverged, and were never corrected; others had the hairs ſo ſmall that it was very difficult to perceive the colours produced by them unleſs they fell on the eye. Glaſs concaves were freer from theſe hairs, but they were much more hurt by dark ſpots, &c. In general the hairs are ſo ſmall in well wrought metals that they do little hurt; but when enlarged by any length of expoſure to the light and heat in ſolar obſervations, they produce irregularities

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round the image. Such at leaſt I take to be the explanation of the phenomenon obſerved at Paris by M. de Barros during the tranſit of mercury in 1743, and recorded in Phil. Tranſ. for 1753. But there is another more ſerious impediment to the performance of reflectors, and which it is to be feared we have no means of removing. In making the experiments of which the hiſtory has been given, on viewing attentively the ſurface of the ſpeculum, every part of it was ſeen covered with points of colours, formed by reflexion from the ſmall ſpecular particles of the body. I never ſaw a ſpeculum free in the leaſt from theſe; ſo that the image formed in the focus muſt be rendered much more dim and confuſed by them than it otherwiſe would be.

III. The laſt concluſion which may be drawn from theſe experiments is a very clear demonſtration in confirmation of what was otherwiſe ſhewn, concerning the difference between coloured images produced by reflexion and thoſe made by flexion. This complete diverſity is moſt evident in the experiments with ſpecula, the colours produced by which, in the form of fringes and rings, ought, as well as the others deſcribed as images by reflexion in Obſ. 11, to be the ſame in appearance with thoſe formed by pins; whereas no two things can be more diſſimilar.

It remains to examine the 6th propoſition. For this purpoſe I made the following obſervations:

*Obſervation* 1. Having procured a good ſpecimen of Iceland cryſtal, I ſplit it into ſeveral pieces, and choſe one whoſe ſurface was beſt poliſhed. I expoſed this to a ſmall cone of the ſun's light, and received the reflected rays on a chart; nothing was obſervable in the image farther than what happens in reflexion from any other poliſhed body. Some pieces indeed doubled and tripled the image, but only ſuch as were rough on the ſurface, and conſequently preſented ſeveral ſurfaces to the rays. When ſmooth and well poliſhed, a ſingle image was all that they formed. The ſame happened if I viewed a candle, the letters of a book, &c. by reflexion from the Iceland cryſtal.

*Obſervation* 2. I ground a ſmall piece of Iceland cryſtal round at the edge, and gave it a tolerable poliſh here and there by rubbing it on looking-glaſs, and ſometimes by a burniſher (it would have been next to impoſſible to poliſh it completely). I then placed the poliſhed part in the rays near the hole in the window-ſhut, and ſaw the chart illuminated with a great variety of colours by reflexion, irregularly ſcattered as deſcribed above*. I therefore held the edge in the ſmoke of a candle and blackened it all over, then rubbed off a very little of the ſoot, and expoſed it again in the rays. I now got a pretty good ſtreak of images by reflexion, in no reſpect differing from thoſe made in the common way. Nor could I ever produce a double ſet or a ſingle ſet of double images by any ſpecimen properly prepared, either on a chart by the rays of the ſun, or on my eye by thoſe of a candle.

*Obſervation* 3. I ground to an even and pretty ſharp edge two pieces of Iceland cryſtal, and placed one in the ſun's rays. At ſome feet diſtance I viewed the fringes with which its ſhadow was ſurrounded, and ſaw the uſual number in the uſual order. I then applied the other edge ſo near that their ſpheres of flexion might interfere in the manner before deſcribed†, and thus the fringes might be diſtended: ſtill no uncommon appearance took place, nor when other bodies were uſed with one edge of cryſtal, nor when poliſhed pieces

* Phil. Tranſ. for 1796, p. 270, or Phil. Journal I. 594.

† Ibid. p. 256, or Phil. Journal I. 587.

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of different ſhapes and ſizes were employed. The ſame things happened by candle-light, and alſo by refracted homogeneal light. In ſhort, I repeated moſt of my experiments on flexion with Iceland cryſtal, and found that they were not changed at all in their reſults.

*Obſervation* 4. Having great reaſon to doubt the accuracy of an experiment tried by Mr. Martin, and in which, by a priſm of Iceland cryſtal, he thought ſix ſpectra were produced, I was not much ſurpriſed to find that a priſm made by poliſhing the two contiguous ſides of a parallelopiped of Iceland cryſtal produced only two equal and parallel images, in whatever poſition the priſm was held. But though, from the imperfect account which Martin gives of this appearance, it was impoſſible to diſcover his error from his own words, yet chance led me to find out what moſt probably had miſled him; for, looking at a candle through the oppoſite ſides of a ſpecimen of Iceland cryſtal, I ſaw four coloured images (beſides two white ones) of the candle. Theſe were parallel to one another, and in the ſame line as repreſented in fig. 7, plate VII. where E repreſents the two regular images, G and F two others coloured very irregularly, and changing colours as the cryſtal was moved horizontally, ſometimes appeared each two fold, and its two parts of the ſame or different colours. A and B were regularly coloured, and evidently formed by refraction, and reflected back from the ſides. On turning the cryſtal round ſo that its poſition might be at right angles to its former poſition, the images moved round, and were in a line perpendicular to A B, as C D. All this happened in like manner in the ſun's rays; and on viewing the ſpecimen I found it was ſplit and broken in the inſide, ſo as to be lamellated in directions parallel or nearly ſo to the ſides: on theſe plates there were colours in the day-time by the light of the clouds; and it is evident that it was theſe fractures which cauſed the irregular images G and F, for other ſpecimens ſhewed no ſuch appearance. I would therefore conclude, that Iceland cryſtal ſeparates the rays of light into two equal and ſimilar beams by refraction, and no more *.

As to the cauſe of the ſeparation, I would hope that ſome information may be obtained from the experiments I have related: for from them it appears, that this ſingular property extends no farther than to the action of the particles of Iceland cryſtal on the particles of light in their paſſage through the body; and from Obſ. 4, it is farther evident, that it is not owing to the different properties which Sir Iſaac Newton conjectures the different ſides of rays to have; for, if this were the cauſe, when the rays paſs between two pieces of cryſtal an uncommon flexion would take place. Laſtly, another fact (miſ-ſtated by Bartolin † and Romé de Liſle ‡) ſhews that the unuſual refraction takes place within the body, while the other, like all refractions, begins at ſome ſmall diſtance before the rays enter.

The writers juſt now quoted aſſert, that if the cryſtal be turned round ſo as to aſſume different poſitions, there is one in which the line appears ſingle. The fact is very different,

* Mentioning this account of Martin's miſtake to Profeſſor Robiſon of this univerſity, I was pleaſed to find a full confirmation of it. It was that excellent philoſopher who ſhewed the appearance to Martin; but he not underſtanding it, took the liberty of publiſhing the obſervation as his own, after firſt mangling it in ſuch a way as to give him indeed ſome pretext for the appropriation. The Profeſſor merely mentioned his having communicated it to Mr. Martin: how the latter uſed it we have ſhewn in the text: the theory of the appearance is ſomewhat more complex than appears by my obſervations. I was therefore pleaſed to find that the Profeſſor was in poſſeſſion of the true account of it, which is however foreign to the preſent purpoſe. B.

† Experimenta Cryſtalli abridged in Phil. Tranſ. vol. v.

‡ Criſtallographie, vol. i.

as follows: When the cryſtal is turned round, the unuſual image turns round alſo, and appears above the other: the greateſt diſtance between the two images is when they are parallel to the line biſecting one of the acute angles of the parallelogram through which the rays paſs: when the images are parallel to a line biſecting one of the obtuſe angles they ſeem to coincide; but they will be found, if obſerved more nearly, to coincide only in part. Thus (in fig. 9, plate VII.) A B and C D are the two black lines at their greater diſtance, and their extremities A and C, B and D, are even with one another; that is, the figure formed by joining A and C, B and D, is a rectangle. But in the other caſe (fig. 8), A B and C D being the lines, the ſpace C B (equal in depth of colour to the real line on the paper) is the only place in which the lines (or images) coincide. The ſpace A C of A B, and B D of C D are ſtill of a light colour, and the two lines A B and C D do not coincide, by the difference A C or B D; that is, by the difference O P, the greateſt diſtance (fig. 9). In ſhort, the unuſual line's extremities deſcribe circles (in the motion of the cryſtal) whoſe centres are the extremities of the uſual line, and whoſe radii are the greateſt diſtance. From this it appears evident, that the unuſual image is formed within the cryſtal, and turns round with the ſide of the particle or rhomboidal maſs of particles which forms it. Farther, it is evident that the power which produces the diviſion of the incident light is very different from common refraction, from the motion, and the effect taking place when the rays are perpendicular. Suſpecting, therefore, that it might be owing to flexion, I made the following experiment, which undeceived me:

*Obſervation* 5. I covered one ſide of a ſpecimen of Iceland cryſtal three inches deep with black paper, all but a ſmall ſpace $\frac{1}{30}$ of an inch in diameter, and placed a ſcreen with a hole of the ſame ſize, ſix feet from the hole in the window-ſhut of my darkened chamber, ſo that the rays might paſs through the ſcreen and fall on a priſm placed behind, to refract them into a ſmall and well defined ſpectrum, which was received on a chart two feet from the priſm. This ſpectrum I viewed through the cryſtal, and of courſe ſaw it doubled; but the two images were by no means parallel: the unuſual one inclined to the red, and its violet was conſiderably farther removed from the violet of the other, than the two reds were from one another; which ſhews that the moſt refrangible or leaſt flexible rays were fartheſt moved from their courſe by the unuſual action, and proves this to be very different from flexion*.

From all theſe obſervations this concluſion follows: that the remarkable phenomenon in queſtion ariſes from an action very different from either refraction or flexion, and whoſe nature well deſerves to be farther conſidered. It may poſſibly belong to the particles of Iceland cryſtal, and in a degree to thoſe of rock cryſtal, from the form and angles of the rhomboidal maſſes whereof theſe bodies are compoſed. Nor is this conjecture at all diſproved by the fact, that glaſs ſhaped like theſe bodies wants the property; for we cannot mould the particles of glaſs, we can only ſhape large maſſes of theſe; whereas we cannot doubt that in cryſtallization the ſmalleſt maſſes aſſume the ſame form with the largeſt. But then other hypotheſes may perhaps alſo account for the fact, ſuch as atmoſpheres, electric fluid, &c. &c.; ſo that till farther obſervations are made we ought to reſt contented with barely ſuggeſting the query. In the mean time, reſerving to a future opportunity ſome inquiries concerning the chemical

* When a candle or line is viewed through a deep ſpecimen, the unuſual image is tinged with colours.

properties

properties of light, and the nature of the forces which bodies exert on it internally, I conclude at present with a short summary of propositions. But, first, may I be permitted to express a hope, that what has been already attempted (and for which no praise can be claimed farther than what is due to attentive observation, according to the rules of the immortal Bacon) may prove acceptable to such as love to admire the beautiful regularity of nature, or more particularly to trace her operations, as exhibited in one of the most pleasing, most important, and most unerring walks of physical science.

*Proposition* I. The sun's light consists of parts which differ in degree of refrangity, reflexity, inflexity, and deflexity; and the rays which are most flexible have also the greatest refrangity, reflexity, and flexity—or are most refrangile, reflexile, and flexile.

*Proposition* II. Rays of compound light passing through the spheres of flexion, and falling on the bending body, are not separated by their flexibility, either in their approach to, or return from, the body.

*Proposition* III. The colours of thin and those of thick plates are precisely of the same nature, differing only in the thickness of the plate which forms them.

*Proposition* IV. The colours of plates are caused by flexion, and may be produced without any transmission whatever.

*Proposition* V. All the consequences deducible from the theory *à priori* are found to follow in fact.

*Proposition* VI. The common fringes by flexion (called hitherto the "three fringes") are found to be as numerous as the others.

*Proposition* VII. The unusual image by Iceland crystal is caused by some power inherent in its particles, different from refraction, reflexion, and flexion.

*Proposition* VIII. This power resembles refraction in its degree of action on different rays; but it resembles flexion within the body, in not taking place at a distance from it, in acting as well on perpendicular as on oblique rays, and in its sphere or space of exertion moving with the particles which it attends.

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## II.

### *Observations on Bituminous Substances, with a Description of the Varieties of the Elastic Bitumen. By* CHARLES HATCHETT, *Esq. F.R.S. Lond. and Edin. F.L.S. &c.**

### SECT. I.

IT is now generally believed that the bituminous substances are not of mineral origin, but that they have been formed from certain principles of substances belonging to the organized kingdoms of Nature, which, after the loss of animal and vegetable life, have suffered considerable changes by long contact and union with mineral bodies.

These changes have been however so considerable, that the bitumens can no longer be referred to their first origin, and they are therefore regarded by general consent as forming part of the present mineral system.

* Read before the Linnæan Society in June and July 1797.



The

The bituminous ſubſtances are :

| | |
|---|---|
| Naptha, | Jet, |
| Petroleum, | Pit Coal, |
| Mineral Tar, | Bituminous Wood, |
| Mineral Pitch, | Turf, |
| Aſphaltum, | Peat, and |

thoſe combinations of the oxides of certain metals with bitumen called Bituminous Ores*.

Thoſe who are acquainted with the nature of theſe ſubſtances will immediately perceive, that they may be formed into two diviſions : the firſt of which conſiſts of ſimple ſpecies, or unadulterated bitumens : and the ſecond is compoſed of bitumen mixed or combined with the earths, vegetable matter, and metallic oxides ; ſo that theſe appear to merit the name of compound ſpecies.

I ſhall now firſt conſider how the ſimple ſpecies are connected with each other.

## SECT. II.

IT has been the opinion of ſome eminent Naturaliſts and Chemiſts, that naptha is an ethereal oil produced from the more compact and ſolid bitumens by a ſort of natural diſtillation. This however appears to be an hypotheſis founded upon analogy, and ſupported only by a few local facts, which may often be queſtioned. But many facts and obſervations concur to prove that the contrary moſt frequently happens, and that the compact bitumens are often, if not always, formed from naptha and petroleum by inſpiſſation. I will not however now inſiſt upon the proofs of this, as the varieties of the elaſtic bitumen, which I ſhall ſoon deſcribe, will be ſufficient for the purpoſe †.

## NAPTHA.

NAPTHA is a ſubſtance well known to Mineralogiſts, as a light, thin, often colourleſs oil, highly odoriferous and inflammable, which is ſometimes found on the ſurface of the waters of ſprings, and at other times iſſuing from certain ſtrata.

When expoſed to the air, it becomes at firſt yellow, afterwards brown, and in the like proportion it thickens, and paſſes into

## PETROL OR PETROLEUM.

THIS has a greaſy feel, is thicker than the preceding ſubſtance, is tranſparent or ſemi-tranſparent, and of a reddiſh or blackiſh brown colour. By air it becomes like tar, and then is called

* As I intend only here to notice the modifications of naptha and petroleum, I have not mentioned amber and the honey-ſtone.

† Bergman was of opinion, that the liquid bitumens were often, if not always, formed from thoſe which are ſolid, by the means of ſubterraneous heat; and expreſſes himſelf thus: " Cæterùm ad fidem pronum eſt, naptham, petroleum, bituminoſoſque liquores, quibus abundat Aſia, plures harum materierum exhibens non tantùm ſcaturigines, ſed rivulos quoque, quibus etiam, parcius licet diſtributis, Auſtralis Europa non caret : probabile, inquam, eſt, has pinguedines liquidas variis antea terris inhæſiſſe exſiccatas, et mediante calore ſubterraneo, ſi non ſemper, ſæpe tamen fluiditatem recuperâſſe. Novimus ignem in alto haud raro agere, quamvis in ſuperficie vix obſcura ejuſdem indicia inveſtigare liceat: novimus præterea e ſicco aluminari ſchiſto petroleum extorqueri juſto caloris gradu, cui arte exponitur.—Bergman de Productis Vulcaniis Opuſcula, tom. iii. p. 238.

## MOUNTAIN OR MINERAL TAR, BITUMEN PETROLEUM TARDE FLUENS.

THIS substance is viscid, and of a reddish or blackish brown or black. When burned, it emits a disagreeable bituminous smell, and by exposure to the air it passes into

## MOUNTAIN OR MINERAL PITCH—BITUMEN MALTHA.

THE mineral pitch much resembles common pitch, and, when heated, emits a strong unpleasant odour, like the former substance. When the weather is cold, it may be broken, and then exhibits, internally, a glassy lustre; but when warm, it is softened, and possesses some tenacity. It is however susceptible of a superior degree of induration, and then becomes

## ASPHALTUM—BITUMEN ASPHALTUM—PETROLEUM INDURATUM.

THIS is a light, brittle substance, of a brownish black, or black. When broken, it shews a conchoidal fracture with a glassy lustre. It has little of the bituminous odour, unless it is rubbed or heated. It easily melts, is very inflammable, and, when pure, burns without leaving any ashes.

In this manner, naptha, by inspissation, passes successively through different states until it becomes asphaltum, which appears to be the ultimate degree of induration which the pure bitumens derived from naptha can receive.

I have at this time specimens before me which prove these gradations; and I have seen a remarkable instance in a bitumen brought from the Island of Trinidad, which exhibits mineral tar passing into mineral pitch, and lastly into asphaltum*.

## SECT. III.

THE division which comprehends the simple bituminous substances derived from naptha, may therefore be considered as terminating in asphaltum; but nature appears to have glided on by an uninterrupted chain which connects the simple bitumens with those which we have called compound; and this effect is produced by the gradual increase of the carbonic principle, and the introduction of extraneous matter, the different quantity of which, together with the greater or less degree of mixture or of chemical union, occasion considerable changes in these substances, so that they are gradually removed from those characters which distinguish the pure bitumens.

To form an accurate table of these gradations, it would be necessary to have comparative analyses of the different bituminous substances, and also to contrast the analyses with the properties of these bodies. But at present these analyses, for the greater part, are wanting; and although at some future time I intend to attempt a series of such experiments, I must now content myself with the observations and facts which I have been able to collect†.

* The progressive changes of naptha into petroleum, mineral tar, mineral pitch, and asphaltum, appear to be caused by the gradual dissipation of part of the hydrogen of the bitumen, and the consequent development or disengagement of carbon. Hence, I am inclined to believe, arise the changes of colour, the degrees of inspissation, and the increased proportion of carbon found in those substances by chemical analysis. I would be understood however to mean that the carbon is only relatively increased, in respect to the other ingredients, in a given quantity of these bitumens, and that it predominates in proportion to the dissipation of a certain portion of the hydrogen, which was originally necessary to the forming of the bitumen in conjunction with the carbon.

† This paper was written and read before I had seen the ingenious experiments which the celebrated Mr. Kirwan has published, in the last edition of his Elements of Mineralogy.—Vide vol. ii. p. 514, (or Philos. Journ. I. 487.)

From theſe I am of opinion, that the moſt immediate gradation from aſphaltum (which is the laſt of the ſimple bitumens) into thoſe which are compound, takes place in the ſubſtance called

## JET.

Jet is a ſubſtance well known to be of a full black, ſometimes however inclining to brown. It is conſiderably harder and leſs brittle than aſphaltum. It breaks with a conchoidal fracture, and the internal luſtre is glaſſy. It has no odour except when heated, and it then reſembles aſphaltum. It melts in a ſtrong heat, and, when burned, leaves an earthy reſiduum.

Wallerius conſidered jet as aſphaltum which had become indurated by time, and Mr. Fourcroy is of the ſame opinion *. Others again have arranged it with the varieties of coal †. I am inclined however to believe, that it is neither aſphaltum nor coal, but an intermediate ſubſtance which may be regarded as the firſt gradation from the ſimple bitumens into thoſe which are compound. The matter of aſphaltum undoubtedly enters into it in a large proportion, and has conſequently ſtamped ſeveral of its characters upon it; but the increaſe of carbon, and of the extraneous or earthy matter which is intimately mixed or rather combined with it, has had ſo much influence, that the characters of coal are alſo in ſome meaſure apparent, and are rendered the more ſtriking by the ſimilarity of certain local circumſtances which attend theſe two ſubſtances. The characters of coal are however by no means fully eſtabliſhed in jet; but from this we paſs immediately to another, in which theſe characters cannot be queſtioned.

This is the ſubſtance called

## CANNEL COAL,

which is of a full black, of a ſmooth, ſolid, even texture; it breaks in any direction, and the tranſverſe fracture is conchoidal. It burns well, and is ſo compact that it is often employed, like jet, to be formed into trinkets.

The great reſemblance which cannel coal has to jet in many of its properties, induces me to regard it as the next gradation of the compound bituminous ſubſtances, and as the leading variety of coal from which the others follow according to the degree of their bituminous character.

The limits of this paper will not allow me to enter into a circumſtantial account of all the other varieties of pit-coal; neither is it neceſſary, after the gradations of aſphaltum to jet, and of jet to coal, have been noticed. I ſhall not therefore deſcribe the varieties of coal known by divers names in different countries, and even in different provinces, ſuch as thoſe called in England caking coal, rock coal, ſplent coal, &c. &c.; but ſhall only obſerve, that the pit-coals in general appear to be compoſed of bitumen intimately mixed, or rather combined, with various proportions of carbon and earthy matter; and according to the intimacy of the union, and the exceſs of one or other of the ingredients, ſo the compound poſſeſſes more or leſs the characters of perfect coal, or, by various ſhades, paſſes into certain earthy or ſtony ſubſtances, which, although impregnated with bitumen, do

* Elémens d'Hiſt. Nat. et de Chimie, tom. iii. p. 456.

† Widenmann's Handbuch der Mineralogie, p. 628.

not

not merit the appellation of coal, and these also at length gradually lose the bituminous character *.

It is likewise worthy of notice, that the quantity of earthy matter does not appear to be the principal cause why pit-coals do not burn with the rapidity which is to be perceived in some other earthy substances impregnated with bitumen. For we may conclude, that the slow combustion of coal proceeds from the joint effects produced partly by the relative proportions of the bituminous, carbonaceous, and earthy ingredients, and partly by the more or less perfect degree of mixture which connects them together, and which degree of mixture, I believe, in many cases, nearly approaches to chemical union, if not actually so: when, therefore, the degree of mixture is so perfect as that every particle of bitumen is connected with much carbon or earthy matter, it is not surprising that the rapid combustible property of the former should be checked in a considerable degree; and, by a parity of reasoning, when the mixture is gross and imperfect, so that it consists of a stony or earthy substance, which has simply imbibed bitumen, it is natural to expect that the bitumen (although less abundant than in coal) should enter readily into combustion, which is vehement in proportion to the shortness of its duration; and this we find to be the case in many earthy substances, and loose sand-stones which are simply impregnated with bitumen.—To return, however, to the varieties of coal, I must observe, that, from the causes above-mentioned, the different characters and properties of coal appear to me to be produced. That in this manner, perfect pit-coal passes into schistose or slaty coal; and this again, by certain gradations, passes into the varieties of combustible or bituminous schistus; which also, by the gradual decrease of the bituminous ingredient, become at length confounded with the varieties of the common or argillaceous schistus.

We have a remarkable example of this in the gradations of bituminous schistus into argillaceous schistus, which are to be observed at Kimmeridge, on the coast of Dorsetshire, where a peculiar bituminous schistus is found, which is used as fuel by the inhabitants, and is improperly called Kimmeridge coal.

By the series of gradations which have been noticed in the foregoing pages, the simple bituminous substances appear to pass into those which are compound; and these also, by declining shades, at last pass into substances appertaining to the class of earths and stones.

In the compound bituminous substances the prevalent earthy ingredient is for the greater part generally, if not always, argillaceous; and although certain calcareous grits (such as the Portland stone †) as well as limestones and marbles are found impregnated with bitumen, yet I know not of any instance in which this happens to the degree requisite to form a combustible substance.

This cursory view of the simple bitumens, and of their combinations, would be sufficient as an introduction to the principal subject of this paper; but, to complete the series, I shall make some observations on the vegetable substances which contain bitumen, and shall afterwards mention the mixtures of bitumen with metallic oxides.

* From Mr. Kirwan's experiments it appears that carbon is a constituent principle of coal, and that the presence of it is a principal cause of those modifications which produce the species. It even seems chiefly to form the Kilkenny coal.—Kirwan's Elements of Mineralogy, vol. ii. p. 521.

† The Portland stone, when recently broken in the quarries, emits a strong bituminous odour, like the bituminous limestone or stink-stone. It is also full of extraneous fossils, or at least the vestiges of them.

SECT. IV.

## SECT. IV.

WHEN we confider the facts which apparently prove that vegetables have contributed principally to the formation of bitumen, we have every reafon to expect that mixtures of vegetable matter with bitumen fhould frequently occur. But by the mixture of bitumen with the parts of vegetables, we underftand the remains and parts of vegetables mixed and connected with the bitumen which they themfelves have produced.

This feems to be the nature of the fubftance called

### BITUMINOUS WOOD, as well as of TURF and PEAT.

BITUMINOUS or foffil wood is found in many places; but in refpect to that which is found at Bovey, near Exeter, and which is therefore called Bovey coal, there are fome peculiarities which deferve to be mentioned. The Bovey coal is a dark brown, light, brittle fubftance, which in texture and other external properties much refembles wood which has been half charred. It is not found as fcattered logs or trunks, but forms regular ftrata.

The pits are on a heath which is flat and fandy; the ftratum of fand is however but thin, after which a pale brownifh grey clay is found mixed with quartz pebbles. This prevails to about fix feet, at which depth the firft ftratum of the coal commences. The quality of this is however much inferior to that of the fubfequent ftrata, which in all amount to feventeen, producing a depth of nearly feventy-four feet from the furface. Between each ftratum of coal is a ftratum of clay. The direction of the ftrata is from eaft to weft, and the inclination or dip is from north to fouth. The inferior ftrata are thought to afford the beft coal, and the coal is more folid and of a better quality towards the fouth. The thickeft ftratum of coal is from fix to eight feet *.

The Bovey coal burns readily with a flame like half-charred wood: it does not crackle, and, if but moderately burned, forms charcoal; or if completely burned, it leaves a fmall quantity of white afhes exactly fimilar to thofe of wood. The fmell of it when burning alfo refembles that of wood, with a faint difagreeable odour. It is certainly very remarkable that this fubftance fhould form regular ftrata, although it poffeffes the texture and moft of the properties of wood; and that thefe ftrata do not exhibit any of thofe irregularities on their furfaces, which might be expected, on the fuppofition that they were formed by the roots, trunks, and branches of trees long buried in the earth. It is alfo difficult to imagine wood to have been tranfported and depofited in this place at feventeen different periods, and yet it muft be allowed that thefe ftrata have been formed by fucceffive operations. I muft confefs, that after having twice vifited and examined the fpot exprefsly for the purpofe, I ftill find myfelf utterly unable to offer any opinion upon the fubject.

The characters of bitumen are but little apparent in the Bovey coal, and the fuperior ftrata even appear to have loft a portion of their combuftible principle, while the inferior ftrata poffefs it. The lower parts alfo of thefe ftrata are more compact and more combuftible than thofe parts which are immediately upon them †.

Another

* In the winter, twelve men can raife about 120 tons of this coal in a week, the whole of which is employed in a neighbouring pottery.

† At about 100 yards to the weft of the pits, is a bog of confiderable extent, where peat is cut, and decayed roots and trunks of trees are found, which do not, however, in the leaft approach to the nature of the Bovey coal,

Another remarkable ſort of foſſil wood, which much reſembles the Bovey coal, and in like manner is arranged among the bituminous woods, is that found in Iceland, which is called by the inhabitants Surturbrand. This is rather harder than the Bovey coal, but in every other reſpect is the ſame. It alſo forms ſtrata many feet in thickneſs; but it is very extraordinary that theſe ſtrata appear to be formed of trunks of trees, which, in their tranſverſe ſection, exhibit the concentric circles of their annual growth, with this difference, that the trunks have been ſo compreſſed as to be nearly flat, ſo that the circles appear like parallel lines connected at their extremities by a ſhort curve.

I did not obſerve ſuch an appearance at Bovey; but this would depend upon the poſition of the trunks of the trees, in reſpect to the ſection of the ſtrata.

Chaptal *, Troil †, Bergman ‡, and many others, have been of opinion that the ſurturbrand is wood which has been charred by the heat of the lava. But I cannot diſcern why it ſhould be ſuppoſed that it has been acted upon by fire, any more than that the Bovey coal has been ſubjected to the effects of the ſame agent. The qualities of the two ſubſtances are the ſame; and as (from Archbiſhop Troil's and Profeſſor Bergman's account) the ſurturbrand is ſtratified, I think we may venture to pronounce that the circumſtances under which they are found, are alſo ſimilar §. The whole, therefore, of the opinion in favour of fire, appears

coal. Whether this bog has been in any manner connected with the formation of the above-mentioned ſubſtance, I do not pretend to determine.

A yellowiſh brown compact ſubſtance, which in colour and fracture reſembles ferruginous clay, is alſo found occaſionally with the Bovey coal: it is brittle, and is highly inflammable; it melts like a bitumen, and emits a ſmoke which in ſmell reſembles amber. This ſubſtance is but rarely found.

* Elements of Chemiſtry, vol. iii. p. 199.

† Von Troil's Letters, p. 43.

‡ Quid de ligno foſſili Iſlandiæ ſentiendum ſit, gnaro in loco natali contemplatori decidendum relinquimus. Interea, ut cum Vulcani operationibus nexum credamus, plures ſuadent rationes, quamvis huc uſque modum ignoremus, quo ſitum texturamque adquiſiverunt hæc ſtrata. Scilicet truncis arborum perquam craſſis conſtant, qualis in Iſlandiâ nullibi reperiuntur, et ne quidem hoc tempore creſcere poſſe videntur. Hi ſitu horizontali in ſtratis multorum pedum craſſitiei congeſti ſunt et petroleo plus minus penetrati, non jam molli, ſed optimè indurato, a quo tam nigrorem, quam flammæ ſub deflagratione qualitatem mutuantur. Sed quod in primis attentionem meretur, eſt truncorum in lamellas planas compreſſio.

Ponamus truncum arboris cujuſdam tranſverſim ſectum, hinc, uti notum eſt, figura oritur in orbem rediens circiter circularis, quæ omnia monſtrat annotina incrementa, extimo propemodum parallela. Fingamus jam talem ſectionem in tenuem laminam compreſſam, et veram habebimus ligni foſſilis, de quo heic agitur, ideam; nam in magnis hujus materiæ fruſtis, tranſverſim ſectis, quemlibet annotinorum orbium viſu perſequi licet, ita plerumque coactum, ut duas lineas fere parallelas exhibeat, quarum extrema brevi flexura ſunt adunata.—Quæ autem immanis requiritur vis, ut truncus cylindricus ita complanetur? Nonne antea particularum nexus putredinis quodam gradu fuerit relaxatus? Certe, niſi compages quodammodo mutatur, quodlibet pondus incumbens huic effectui erit impar. Cæterùm idem obſervatur phænomenon in omni ſchiſto argillaceo.

Orthoceratitæ, quæ in ſtrato calcareo conicam figuram perfectè ſervant, in ſchiſto planum fere triangulare compreſſione efficiunt. Idem valet de piſcibus, conchis, inſectiſque petrifactis. Cauſa adhuc latet, ſed in utroque caſu ſine dubio eadem eſt, et digna quæ exploretur. Obſervatu quoque dignum eſt, quod idem reperiatur effectus, quamvis ſtratum calcareum ſub ſchiſto collocatum ſit et majori ideo pondere comprimente onuſtum.——Bergman de Productis Vulcaniis Opuſcula, tom. iii. p. 239.

§ "It is found (the ſurturbrand) in many parts of Iceland, generally in the mountains, in horizontal beds; ſometimes more than one is to be met with, as in the mountain of Lack in Bardeſtrand, where four ſtrata of ſurturbrand are found alternately with different kinds of ſtone."—Troil's Letters, p. 42.

to reſt on the volcanic nature of Iceland; but it ſurely would be going too far were we to aſcribe to fire all the phenomena which are obſerved in volcanic countries.

Bovey coal, like the ſurturbrand, reſembles half-charred wood; and I will allow, and indeed am diſpoſed to believe, that it is in a ſtate nearly ſimilar; but from this it does not follow that fire has been the cauſe.

Carbon is known to be one of the grand principles of vegetables, and alſo as that which is the moſt fixed, excepting the ſmall portion of the earths contained in them. As a fixed principle, carbon appears to form, in great meaſure, the vegetable fibre; and after a certain degree of combuſtion, (by which the other principles have been diſſipated,) it remains, and the particles of it keep the ſame arrangement which they poſſeſſed when the vegetable was complete. If, however, the combuſtion has been carried on with the free acceſs of air, the carbon enters into combination with oxygen and caloric, and forms carbonic acid.

We have many examples in which carbon is formed or rather liberated from thoſe ſubſtances with which it was combined in vegetables; and theſe are now explained as effects ſimilar to thoſe of combuſtion, although fire has not been the cauſe. In both caſes the carbon has been freed from the more volatile principles; and under circumſtances not favourable to the union of carbon with oxygen, the former muſt neceſſarily remain more or leſs undiminiſhed.

During the combuſtion of vegetable matter, the more volatile principles contained in the vegetable fibre (which with carbon alſo form the reſinous and other ſimilar ſubſtances) appear to be firſt ſeparated; and in proportion to this ſeparation, the other more fixed ſubſtance, which we call carbon, is developed.

Thus, by the progreſs of combuſtion, wood becomes brown, and afterwards black; ſo that the ſtate of the wood ſhews the degree of combuſtion to which it has been ſubjected, or, in other words, how far the ſeparation of the other principles from carbon has been effected.

Combuſtion is therefore a ſpecies of analyſis by which the principles of vegetables are ſeparated, according to their affinities, and according to their degree of volatility. By this operation hydrogen and azote (if it be preſent in the vegetable) are firſt diſengaged and form new combinations, while the carbon is the laſt which is acted upon; ſo that unleſs a ſufficient quantity of oxygen be preſent, it remains fixed and unchanged.

But the ſame ſeparation of the vegetable principles happens whenever vegetables in the full poſſeſſion of their juices are expoſed to circumſtances which favour the putrid fermentation.—As in combuſtion, ſo by the progreſs of putrefaction does the vegetable loſe its colour, become brown, and afterwards black; at the ſame time a gas is diſcharged, which is compoſed of hydrogen, azote, and carbonic acid.

When combuſtion is long continued with the free acceſs of air, the whole of the carbon is diſſipated in the ſtate of carbonic acid; but in the proceſs of putrefaction a conſiderable portion of carbon commonly remains even long after the putrid fermentation has ceaſed. Although, therefore, it is as readily developed by putrefaction as by combuſtion, it is not, however, when liberated from the other principles, ſo ſpeedily diſſipated by the former as by the latter proceſs.

According to the degree of combuſtion within certain limits the carbon is more or leſs apparent, and the like prevails according to the degree of putrefaction; ſo that whenever

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the causes which have promoted this species of fermentation have ceased, the vegetable substance will remain with more or less of its first principles, and with more or less visible carbonic matter, according to the degree of putrefaction which has prevailed, and the vegetable substance will consequently have the appearance and properties of wood which has been charred more or less.

To this cause, therefore, I am inclined to attribute the formation and appearance of the Bovey coal and surturbrand; and I believe that the portion of oily and bituminous matter, which I have obtained from them by distillation, is nothing more than the remainder of the vegetable oils and juices which have been partly modified by mineral agents *.

[ *To be continued.* ]

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## III.

### *New Methods of affording, at an inconsiderable Expence, the Heat and the Water required for performing Experiments in Chemistry. By Citizen* GUYTON †.

THERE is but one sure road to arrive at truth in natural philosophy, namely, by consulting nature herself by experiments. Independent of the sagacity necessary to direct these to objects precisely determinate, and to combine the means of operating, there is likewise an art of performing them, or, to speak more properly, of giving facility without diminishing the certainty of their results. To awaken the industry of philosophers with regard to such resources as may be obtained for the multiplication of experiments at the least possible cost, must therefore be a labour of utility to the advancement of science. When Franklin was asked how he could afford the charges of his experiments on electricity, at a time when he was far from being in circumstances of independence, he replied, that a man who could not saw with a gimblet, and bore with a saw, was not fit for an experimental philosopher. The services which Bergman has rendered to chemistry, and particularly to mineralogy, by the introduction of the blow-pipe, are well known. What a number of valuable observations would still be wanting, if he had not put this instrument into the hands of those who were unable to procure, or have access to the furnaces of the elaboratory!

It is in consequence of these reflections, and the invitation I have received for that purpose, that I have determined to describe the small manipulations by which I obtain a very considerable saving of fuel and of distilled water in chemical experiments, to which I may add the saving of time, that most inestimable of all the desiderata for experimental research.

* "Coal not only forms the residuum of all vegetable substances that have undergone a slow and smothered combustion, that is, to which the free access of air has been prevented, but also of all putrid vegetable and animal bodies: hence it is found in vegetable and animal manures that have undergone putrefaction, and is the true basis of their ameliorating powers: if the water that passes through a putrefying dunghill be examined, it will be found of a brown colour; and if subjected to evaporation, the principal part of the residuum will be found to consist of coal. All soils steeped in water communicate the same colour to it in proportion to their fertility; and this water being evaporated, leaves also a coal, as Messrs. Hassenfraz and Fourcroy attest."—Kirwan on Manures, p. 154, vol. v. of the Transactions of the Royal Irish Academy.

† Read before the National Institute of France, the 26th Brumaire, in the year 6, and inserted in the 24th volume of the Annales de Chimie, page 311.

In the ſecond volume of the memoirs of the ancient academy of Dijon, I gave a deſcription of a box containing a kind of portable laboratory, compoſed of a lamp with three wicks, diſpoſed in the figure of an equilateral triangle, to form an internal current of air, with ſupports for the different veſſels of digeſtion, diſtillation, evaporation, &c. I made a ſolution of ſilver with common aqua fortis and the metal in an alloyed ſtate, which anſwered very well as a re-agent, without having occaſion for any other utenſils but this box and apothecary's phials, which are every where to be found. A number of theſe boxes have been fitted up by Citizen Dumoutier, more particularly for travellers, and I have reaſon to think that they have proved uſeful. But this apparatus muſt neceſſarily be confined in its application, and is different from the object I purpoſe to deſcribe at preſent.

Ten years ago, I conſtructed a lamp, on the principles of Citizen Argand, with three concentric circular wicks, each having an interior and exterior current of air. The effect ſurpaſſed my expectations with regard to the intenſity of the heat; but it was difficult to prevent the deſtruction of the hard ſolder round the wicks; and the glaſs retorts were frequently melted at the bottom, and disfigured. It may eaſily be imagined, that the quantity of oil conſumed was conſiderable; and as it could not be uſed at the ſame time for giving light, it had, to ſay the truth, no more than a remote application to the object of the preſent communication.

A ſhort time afterwards it occurred to me, to ſubſtitute, inſtead of the glaſs chimney of Argand's lamp, a cylinder of copper with an indented part or ledge a few millimetres * above the flame, to perform the office of the indented chimney of glaſs, and by that means to render it practicable to raiſe the wick to a certain height without ſmoking. This cylinder has three branches like a chaffing-diſh. By this apparatus two or three decilitres of water (about half an Engliſh wine pint) may be brought to boil in a copper or glaſs veſſel in about ſix or ſeven minutes. It has ſerved, and I ſtill uſe it, for a number of operations; but it was not till after I had obſerved the degree of heat obtained from the lamp in its ordinary ſtate, and particularly ſince I have ſubſtituted inſtead of the metallic tube a chimney of glaſs cut off at the length of three centimetres (rather more than one Engliſh inch) above the contraction, that I perceived all the advantages it was capable of affording; and that by means of a moveable ſupport for the reception of the different veſſels, which may be fixed at pleaſure by a thumb-ſcrew, this lamp furnace, at the ſame time that it gives light, and conſequently without any additional expence, may with facility be uſed for almoſt every one of the operations of chemiſtry; ſuch as digeſtions, ſolutions, cryſtallizations, concentrations; the rectification of acids; diſtillations on the ſand-bath, or by the naked fire; incinerations of the moſt refractory reſidues; analyſes with the pneumatic apparatus, or of minerals by the ſaline fuſion, &c. &c. I have not hitherto met with any exception but for complete vitrifications and cupellations; for even the diſtillations to dryneſs may be performed with ſome precautions, ſuch as that of transferring the matter into a ſmall retort blown by the enameller's lamp, and placing its bottom on a little ſand-bath in a thin metallic diſh.

The ſupport, here mentioned, is ſimply a copper ring eight centimetres (3,15 inch) in diameter, which is raiſed or lowered by ſliding on a ſtem of the ſame metal. It is deſcribed in the memoirs of the academy of Dijon as part of the portable laboratory; for which reaſon

* For the value of the new meaſures and weights of France, ſee Philoſ. Journal, I. 332.

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it is unneceffary to fpeak more largely of it in this place*. Nothing more was required but to adapt it to the fquare iron ftem which paffes through the refervoir of the lamp. The connection is made by a piece of wood, in order that lefs of the heat might be difperfed. As the lamp itfelf is capable of being moved on its ftem, it is eafy to bring it nearer or remove it at pleafure from the veffels, which remain fixed; a circumftance which, independent of the elevation or depreffion of the wick, affords the means of heating the retorts by degrees, of moderating or fuppreffing the fire inftantly, or of maintaining it for feveral hours at a conftant or determinate intenfity, from the almoft infenfible evaporation of cryftallizable folutions to the ebullition of acids; properties never poffeffed by the athanor, of which chemifts have boafted fo much. The advantage of thefe will be properly valued by thofe operators, who know that the moft experienced and the moft attentive chemifts meet with frequent accidents, by which both their veffels and the products of their operations are loft, for want of power in the management of the fire.

I muft here enter into fome detail, in order to eftablifh upon pofitive facts the poffibility of applying the heat of a lamp to the operations I have enumerated, as well as to communicate the refults of my experience to thofe who in preference, or for want of more extenfive means, may be inclined to ufe this apparatus. I do not hefitate to fay in preference; for, in the beft appointed laboratory, the lamp will alfo be ufed in fuch operations as may be made with equal facility on the fame quantities, in much lefs time and more conveniently than by the fire of a furnace, by burning in the former inftance one or two decimes (or pennyworths) of oil inftead of five or fix decimes of charcoal. The proof of this has been made in the laboratory of the Polytechnic School, at the conclufion of my laft courfe.

For the analyfis of ftones, fuch as the cryftals of tin, on which I operated before the clafs at the feffion of the firft Meffidor laft, I ufe the fhortened chimney of glafs. I begin by placing the mixture in a capfule of platina or filver of feven centimetres ($2\frac{3}{4}$ inches Englifh) in diameter. I place this capfule on the fupport, and regulate the heat in fuch a manner that ebullition fhall take place without throwing any portion of the matter out of the veffel. As foon as its contents are perfectly dry, I transfer them into a very thin crucible of platina, of which the weight is not quite eleven grammes ($252\frac{1}{2}$ grains Englifh), and its diameter forty-five millimetres ($1\frac{3}{4}$ inch Englifh). This crucible refts on a fmall fupport of iron-wire, which ferves to contract the ring; and the wick being at its greateft elevation, with the ring lowered to the diftance of twenty-five millimetres ($9\frac{3}{4}$ inches Englifh) from the upper rim of the glafs chimney, I produce in lefs than twenty minutes the faline fufion to fuch a degree, that from the commencement of the operation the decompofition proceeds as far as to 0,70 of the mineral †.

The fame apparatus, that is to fay, with the fhortened chimney, ferves for oxidations, incinerations, torrefactions, and diftillations to drynefs.

In fuch operations as require a lefs heat, I leave the lamp with its large chimney abfolutely in the fame ftate as when it is ufed for illumination; and by raifing and lowering either

* Several philofophers who have feen this apparatus at work, having requefted me to give a drawing, I have accordingly annexed a defcription of the figures, which reprefent the whole together at the end of this memoir. I think it may be called the Economical Laboratory.

† See the Annales de Chimie, xxiv. 132; or our Journal, I. 545.

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the ring which fupports the veffel, or the body of the lamp if the veffels be fixed in communication with others, I graduate the heat at pleafure. Vinegar diftils without interruption at fix centimetres ($2\frac{1}{3}$ inches Englifh) from the upper termination of the chimney, that is to fay, at 19 centimetres ($7\frac{1}{2}$ inches Englifh) from the flame. Water is made to boil in eight minutes, at the fame height, in a glafs veffel containing five decilitres (one wine pint Englifh), and is uniformly maintained at the diftance of twenty-two centimetres ($8\frac{2}{3}$ inches) from the flame. It will foon be fhewn, that I have another method of fupplying chemifts with diftilled water; fo that I fcarcely ever repeat this operation but when I have no other fupply at hand, or am defirous of avoiding all trouble whatfoever. In this cafe, I obtain two or three decilitres (or quarter pints) of water in the courfe of a winter evening, without the leaft portion of my time being employed in attending to the operation.

I muft not in this place omit to mention a flight obfervation which this procefs has afforded, becaufe it may lead to ufeful applications, and tends to point out one great advantage of this method of operating; namely, that an infinity of circumftances may be perceived, which might not even be fufpected when the whole procefs is carried on within a furnace. I have remarked, as did likewife feveral of my colleagues who were then prefent, that a column of bubbles conftantly rofe from a fixed point of the retort on one fide of the bottom. We were of opinion, that fome particle of matter was in that place incorporated with the glafs, which had a different capacity (probably conducting power) for heat from that of the reft of the glafs. In order to verify this conjecture, I endeavoured the following day to diftil the fame quantity of the fame water in the fame retort, after having introduced a button of cupelled filver, weighing nine decigrammes ($20\frac{1}{2}$ grains). At the commencement of the operation there was a fmall ftream of bubbles from the fame point as before; but a fhort time afterwards, and during the whole remaining time of operating, the largeft and moft inceffant ftream of bubbles rofe from the circumference of the button, which was often difplaced by the motion; and in proportion to the time the product of the diftillation was fenfibly greater. Whence we may conclude, that metallic wires or rods, diftributed through a mafs of water required to be kept in a ftate of ebullition, and placed a little below its furface, would produce, without any greater expence of fuel, nearly the fame effect as thofe cylinders filled with ignited matter which are made to pafs through the boilers *.

It now remains to fhew the economical method of fupplying the water neceffary for experiments.

When water is mentioned in chemiftry, pure water is always meant. In medical prefcriptions it is ufual to prefcribe fpring water, though in many places the water of fprings or ftreams is more loaded with felenite or fulphate of lime than the well water of other places. The fame remark may be applied to river water, which is no doubt more wholefome than

* When we attempt to reafon on this curious fact of the metallic button, there are various circumftances which require to be confidered. It does not feem probable, that a larger quantity of a fluid can be rendered elaftic by a given quantity of heat, unlefs we fuppofe part of the heat to have been wafted in the former procefs. Does the metal, by the excellence of its conducting power, convey a portion of the heat more readily into the mafs of liquid than might have been done by the ordinary procefs of circul tion? Or is the thin ftratum beneath the button fo far infulated as to become more fuddenly elaftic, and, by rifing in that ftate to the furface, to increafe the rapidity of circulation, and the number of points at which vapour can efcape? Would a tuft of filver wire produce the fame effect? &c. &c. N.

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the water of wells in places where selenite or plaister abounds, but which are nevertheless far from being pure, and are necessarily subject to vary according to the quantity of rain water which dilutes that which has remained upon the soluble matter.

Recourse is therefore had to distillation, to purify the water employed in laboratories; but if on the one hand we consider the labour and expence it requires, and on the other hand the quantity which it is necessary to have in readiness for the smallest operations; it will not appear surprising, when I assert, that there are few days in which a chemist does not avoid making some experiment, or obtain uncertain results, for want of having this article in his power. It is only with distilled water that perfect reagents can be prepared; distilled water is consumed in infusions, macerations, solutions, and edulcorations; repeated lotions demand a large quantity of this fluid; it ought to be used even for rinsing vessels; and in order to avoid deceitful conclusions, it is even proper to use it in the hydropneumatic vessels.

I have long been in the habit of supplying most of these demands with rain water; not with that which is directly received, though in fact it is of considerable purity, particularly in countries where there is no reason to fear that plaister should rise with the dust; but the quantity of this would be too small. I have, therefore, used water collected with care from the roofs of houses after the rain has washed the surface. I filter it without delay; and in this manner from time to time I obtain a considerable provision, without much labour and at no expence. But it is evident, that in order to depend on the purity of this water, it is necessary that there should be no gypseous matter in the composition of the mortar of the roof, or the plaistering of the chimneys. This condition does not obtain at Paris; insomuch that I have sometimes found the first water of the gutters more selenitous than that of the Seine in the time of floods. I have thought of a method of supplying this resource, by a process which may be used in all countries; and the success which has attended my trials renders it a duty to communicate it, in order to place the instruments of analysis in the hands of a greater number of operators.

Rain water collected from the roofs of houses which have been previously washed, cannot, and in fact does not, contain any thing but the very small portion of sulphate of lime which it has taken up during its contact with the plaister of the chimneys and the pointing of the ridges. It is necessary, therefore, to deprive it of this, in order to have water in a very pure state. For this purpose I prepare a solution of barytes according to the process* by which our colleague Vauquelin has rendered so easy what Bergman attempted with imperfect success. I pour this solution into the filtered rain water, until, after the precipitation has subsided, the last drop exhibits no alteration of transparency. I even add a small quantity in excess, which shews itself by the vinous colour it gives to paper coloured with fernambouc or brazil wood. This excess soon falls down in the state of carbonate of barytes, by simple exposure to the air. The precipitation may be very suddenly determined, by the addition of water impregnated with carbonic acid. Too much must not however be added, because it would take up a portion of the precipitate. But the spontaneous evaporation of the excess of gaseous acid in the open air would in this case soon restore its purity.

To judge with what facility and trifling expence the whole of the pure water for experiments

* Philosophical Journal, I. 535. Dr. Hope in the Edinburgh Transactions, iv. 36. informs us, that, contrary to the assertions of many chemists, the native carbonate of barytes may be deprived of its acid by mere heat (of a smith's forge, in a black lead crucible). N.

ments may be procured, it is sufficient to obferve, that by ufing an aqueous folution of barytes of which the fpecific gravity was no more than 1,0205, the quantity of 15 grammes in weight (344½ grains Englifh), or 0,1473 cubic metres (4,1 cubic inches Englifh), proved fufficient completely to purify eleven decilitres (2⅓ wine pints Englifh) of water. Confequently one decilitre or part of the fame aqueous folution of barytes will ferve to afford 74,62 parts, or about 8 (French) pints of diftilled water.

I muft add an obfervation, which is very proper to fhew that the collection of rain-water is worth the trouble and care of procuring it in the circumftances moft favourable to its purity. By a comparative operation on rain-water, I found that river water acquired 60 grammes, or four times the quantity of the fame folution of barytes.

I have no doubt but that the aqueous folution of barytes for the purification of water will, in the courfe of time, be introduced into manufactories for dyeing. It will ferve, at a very moderate expence, to render the artift mafter of the fhades he means to produce, without waiting for the feafon in which he confiders his water as moft pure. I gave this advice to a manufacturer who requefted me to analyfe the water of a fmall ftream which fupplied his works.

Thefe obfervations may alfo probably be applied to another purpofe. It is known that water faturated with fulphate of lime is much lefs putrefcible than purer water: would it not be of advantage, in long voyages, to take a fupply of water exprefsly loaded with this earthy falt, and, when it is wanted for ufe, to purify it three or four days before hand by a fmall portion of the folution of barytes?

This folution would occupy little room, and be attended with inconfiderable expence. If it were apprehended that a fmall portion of barytes might remain in folution, which would not in fact be without danger, as this earth is perceptibly noxious, a proof might be made; or, to fpeak more correctly, the depuration might be rendered abfolute by the addition of a few drops of the folution of carbonate of foda. All thefe manipulations are among thofe which may be very eafily practifed by perfons of no chemical experience.

*Explanation of the Figures of the Economical Laboratory, Plate IX.*

*Figure* 1. reprefents the whole apparatus ready mounted for diftillation, with the tube of fafety and a pneumatic receiver.

A is the body or refervoir of the ufual lamp of Argand, with its fhade and glafs chimney. The lamp may be raifed or lowered at pleafure by means of the thumb fcrew B *, and the wick rifes and falls by the motion of the fmall toothed wheel placed over the wafte cup. This conftruction is moft convenient, becaufe it affords the facility of altering the pofition of the flame with regard to the veffels, which remain fixed; and the troublefome management of bended wires above the flame for the fupport of the veffels is avoided, at the fame time that the flame itfelf can be brought nearer to the matter on which it is intended to act.

D, a fupport confifting of a round ftem of brafs, formed of two pieces which fcrew together at about two-thirds of its height. Upon this the circular ring E, the arm F, and the nut G flide, and are fixable each by its refpective thumb-fcrew. The arm alfo carries a

* In the lamps of this conftruction made in London there is a fpring in the focket, fufficiently rigid to prevent the lamp A from falling by its weight when B is unfcrewed. I fuppofe Citizen Guyton's lamp was provided with the fame convenience, but that by overfight it may not have been mentioned. N.

moveable

moveable piece H, which serves to suspend the vessels in a convenient situation, or to secure their position. The whole support is attached to the square iron stem of the lamp by a piece of hard wood I, which may be fixed at any required situation by its screw.

K represents a stand for the receivers. Its moveable tablet L is fixed at any required elevation by the wooden screw M. The piece which forms the foot of this stand is fixed on the board N; but its relative position with regard to the lamp may be changed by sliding the foot of the latter between the pieces O O.

P, another stand for the pneumatic trough. It is raised or lowered, and fixed to its place, by a strong wooden screw, Q.

R is the tube of safety, or reversed syphon, invented by Citizen Welter, and described in the third cahier of the Journal of the Polytechnic School, p. 437 *.

*Fig.* 2. shews the lamp furnace disposed to produce the saline fusion; the chimney of glass shortened; the support D turned down; the capsule of platina or silver, S, placed on the ring very near the flame.

*Fig.* 3. The same part of the apparatus, in which, instead of the capsule, a very thin and small crucible of platina, T, is substituted, and rests upon a triangle of iron wire placed on the ring,

*Fig.* 4. exhibits the plan of this last disposition.

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## IV.

### *An Account of some Experiments made by Mr.* John Cuthbertson, *with a View to determine an unequivocal Method of ascertaining the Power of electrical Machines.*

HOWEVER great the influence and probable importance of electricity may appear in a large class, and perhaps in the whole of natural phenomena, we still find that a number of fundamental experiments remain to be made. Among these there is scarcely a more desirable object than to determine the degree of excitation or quantity of electricity afforded by machines, in proportion to the surface exposed to friction. When philosophers endeavour to communicate to each other the indications of power in their respective electrical apparatus, they either describe the length and appearance of the simple spark from a conductor, or the explosion from a certain measure of coated surface, or else the distance to which the attractive power of the prime conductor is rendered perceptible upon a thread or pendulous body. The first of these methods is subject to variation from the magnitude of the conductor itself, the figure of its termination, and particularly that undulation of

* And also in the 2d vol. of the Annales de Chimie, p. 311. This apparatus serves, in a great measure, to prevent the bad effects of having the vessels either perfectly closed or perfectly open. Suppose the upper bell-shaped vessel to be nearly of the same magnitude as the bulb at the lower end of the tube, and that a quantity of water, or other suitable fluid, somewhat less than the contents of that vessel, be poured into the apparatus: In this situation, if the elasticity of the contents of the vessels be less than that of the external air, the fluid will descend into the bulb, and atmospheric air will follow and pass through the fluid into the vessels: but, on the contrary, if the elasticity of the contents be greater, the fluid will be either sustained in the tube, or driven into the bell-shaped vessel; and if the force be strong enough, the gaseous matter will pass through the fluid, and in part escape. N.

which

which the first account was given in our Journal, vol. i. page 83: and the last method, being subject to modification, not only from the structure of the less essential parts of the machine, but also from the dimensions and figure of the apartment in which the experiments are made, has been accordingly very little used. Electricians have, therefore, with considerable reason, been disposed to avail themselves of the second method, according to the simple computation described in our work last referred to, page 87. But to this method also Mr. Cuthbertson, the constructor of the great Teylerian machine at Haerlem, offers serious objections; in consequence of which he took the trouble to repeat some experiments at my request. These experiments, together with his observations and such remarks as have occurred to myself, will form the subject of the present memoir.

The Honourable Henry Cavendish, Esq., from a series of experiments upon the charges of electrical jars *, has deduced, that the quantities of electricity which coated glass of different shapes and sizes will receive with the same degree of electrization, are directly as the area of the coating, and inversely as the thickness of the glass; and that, when the intensities vary, the quantities of electricity in like circumstances are nearly as the length of the spark. Mr. Cuthbertson's great experience has led him to modify these general conclusions. I have found that in great intensities the length of the spark is much more than in proportion to the charge †; and from some facts hereafter to be related, there is reason to think that a real charge of low intensity cannot be measured either by the length of its very short spark, or even by the number of turns of the machine. Electricians, in general, use the best glass they can procure in their vicinity; whence their conclusions are, for the most part, applicable to one kind of glass only. But Mr. Cuthbertson has observed, that the different kinds of white glass, and still more the green, will require very different quantities of electricity to charge equal surfaces and thicknesses to the same height. He showed me a jar, of which the coating had been cut away until its capacity, as determined by the number of turns of the machine, became equal to that of another similar jar of the same thickness. The coated surface of the former of these two jars might be estimated at more than one-third part less than that of the former. Hence the necessity of some other test of electrical power, different from that which includes the dimensions of the jar as one of its elements, is evident. Mr. C. offers the explosion of steel wire for this purpose; the result of the facts observed by him being, that equal quantities of electricity, in the form of a charge, will cause equal lengths of the same steel wire to explode, whether the jar made use of be of greater or less capacity, within certain limits very easily comprehended in a loose verbal description. The primary object of his experiments was directed to the establishment of this proposition.

July 6th, 1798, I waited on Mr. Cuthbertson at seven in the evening, and found two electrical machines in a state of activity. The first consisted of a glass-plate 24 inches in diameter, rubbed by two pair of cushions, each 5 inches long, proceeding from the extreme of the circumference towards the centre upon opposite radii, whence the whole surface rubbed in each turn was 1193,8 square inches, or 8,29 square feet. The other machine was of the same dimensions, but had two plates and four pair of cushions. A jar fitted up with Lane's electrometer, the balls of which were invariably fixed, was used to ascertain the steadiness of the excitation. When this jar was applied to the prime conductor of the

* Philosophical Transactions, lxvi. p. 196. † Phil. Transf. lxxvi.

single

single plate-machine, it exploded five times in $7\frac{3}{4}$ turns of the winch. Upon applying the same test to the double plate-machine it was found to afford very nearly, or rather more than twice the quantity of electricity. All the following experiments were made with the single plate.

A jar *, No. 1, was applied to the prime conductor: after four turns some ramified flashes struck into the uncoated part, and at the sixth turn a spontaneous explosion took place over the clear glass. It must be remarked, that the mouths of none of the jars had any stopper or covering. Mr. C. then took a glass tube, which he inserted into the jar nearly to the bottom, and breathed twice through it, in order, as he said, to render it more capable of retaining its charge. This process, so contrary to the received opinion of electricians, who carefully avoid all dampness, is considered by him as of the same nature as the experiment of Brook, who found that a jar, the naked part of which was soiled by handling, would retain six times the charge without exploding, which it would have held if perfectly clean †. I had always considered this last experiment as a proof that glass, when greased by handling, does not attract vapour from the air as readily as when clean; and accordingly I have often used tallow as a good extemporaneous varnish for glass pillars. Mr. Cuthbertson's process, however, had the same effect; for the jar did not afterwards exhibit any flash or disposition to explode during the whole evening, though it was occasionally charged with ten and twelve turns. A brass ball supported on a stand by a stick of glass was placed so as to receive the explosion from the jar No. 1, when thus connected with the prime conductor. From this ball hung a small piece of pendulum wire ‡, confined at each end between small forceps constructed for that purpose. The clear portion of the wire which formed part of the circuit was exactly five inches in length. An explosion was passed through a moderate interval or length of spark; and this interval was gradually increased till, at last, the shock became so strong as completely to ignite the wire and divide it near the positive end, where a sparkling globule or two flew out: ten turns of the machine were required to produce this effect, and the length of the explosive spark was $1\frac{1}{4}$ inch.

Another jar, No. 2 §, was applied to the prime conductor along with No. 1, and their outside coatings were connected together. The same quantity of wire as in the last experiment was placed in the circuit, and by the same method an explosion was obtained, which ignited and broke the wire with nearly the same appearances as before. In this case the number of turns were $9\frac{2}{3}$, and the length of spark $\frac{3}{4}$ of an inch.

These experiments evidently confirm the result Mr. Cuthbertson obtained from his former trials; namely, that the quantity of electricity to disperse a given portion of wire will be

* Height of the coating $7\frac{1}{2}$ inches, diameter $6\frac{3}{4}$ inches, both outside measure. Uncoated part $4\frac{3}{4}$ inches perpendicular, though the mouth, in reality, was somewhat smaller than the body of the jar. Thickness 0,16 inch. Hence the surface was about 188 square inches, or $1\frac{1}{3}$ square foot.

† Miscellaneous Experiments and Remarks on Electricity, &c. by A. Brook. Norwich, 1789.

‡ This wire is sold at the watch-tool makers. It is of steel flattened, and is used to make the small spring of the balance in watches. The wire here mentioned is 0,005 inch in breadth and one grain in weight; measures $44\frac{1}{2}$ inches long.

§ Height of the coating $8\frac{1}{2}$ inches, diameter 6,2 inches, both outside measure. Uncoated part $3\frac{1}{2}$ inches perpendicular, though the mouth was, as in No. 1, somewhat smaller than the body of the jar. Thickness 0,17 inch. Hence the surface was about 190 square inches, or $1\frac{1}{3}$ square foot, nearly the same as the other jar.

 the

the same, even though the charged surface should be greatly varied. But it appeared desirable to ascertain the proportional quantities of electricity required to explode different lengths of the same wire. For this purpose 2,3 inches of wire were exploded by the jar No. 1, by five turns of the winch; which was probably too great a quantity, for the ignition was very strong, and deflagrating globules were thrown about. But by a more careful repetition of the experiment with 2½ inches of wire, the ignition and partial melting of the wire were very nearly the same as in the experiments which had been made on lengths of five inches. From these experiments there seems reason to suppose that the quantities of electricity may be as the lengths of the wires exploded.

A battery of fifteen jars, containing about 17 square feet of coated surface, was then used to explode five inches of the wire. Nineteen turns rendered the wire faintly red hot; but 20 turns caused it to explode in the same manner as in the experiments with the jars.

Half the length of wire, namely 2½ inches, was in the next place submitted to the explosion of the battery. Twelve turns ignited the wire, and 15 turns caused it to explode with somewhat more violence than in the experiments with the jars.

At this stage of the process, as the battery had required twice the quantity of electricity to produce the effect which had before taken place with a smaller quantity of coated surface, it became a question whether the length of the circuit, which was six feet on each side, might have influenced the results; and also whether the state of excitation had become less intense. For these reasons, the disposition of the apparatus was altered so that the circuit with the battery was the same as had before been used with the jars; and the trial jar, with Lane's electrometer, was again applied to ascertain the power of the machine. Five explosions were afforded by 7¾ turns, as at first: this experiment was twice repeated, and shewed that the action of the machine continued to be the same as at first.

In this new disposition of the battery five inches of the wire were exposed to the explosion. No effect was produced by 12 turns; but by 21 turns the whole of the wire was dispersed in globules by a strong ignition. I suppose that 20 turns might have dispersed it in the same manner as in the first experiment.

Two inches and a half of the wire were then placed in the circuit. This portion was not affected by an explosion of 12 turns; but by 13 turns it was ignited and broken by the dissipation of a globule or two. Lastly, one inch of the wire was exposed to the shock; it was ignited, and partly dispersed in globules by 10 turns.

The whole of these experiments employed upwards of three hours, during the greatest part of which time the machine was in action. At the conclusion the trial jar was applied: it exploded five times in a little more than eight turns. The trial was repeated twice, and serves evidently to show the steadiness of the excitation, which had diminished only about $\frac{1}{16}$th part during this course of work.

Upon a review of the foregoing experiments, it is obvious that they would require to be repeated and extended, if the general course of Mr. Cuthbertson's former processes were not to be admitted in confirmation of the position, that equal quantities of electricity will ignite and disperse equal quantities of the same wire, without requiring any particular adjustment of the quantity of coated surface, provided the intensity be considerable. From the experiments with the battery it seems reasonable to conclude, that the quantities of electricity required to produce like effects upon wire will be greater, the lower the intensity, when the quantity

quantity of surface is greatly increased; in which case the velocity of the electric fluid may be supposed insufficient for the whole charge to exist in the conducting wire at one and the same time; or its impetus may be less; or, lastly, there may be a considerable waste from the conducting power of the air through the very thin stratum of air through which the explosion at last passes. This last supposition is far from being merely conjectural. For by some experiments on the charge of a plate of air in connection with the gold leaf electrometer, of which I may hereafter give an account, I find that even in very low intensities the electric matter will pass in a constant stream through intervals of about one inch; a conclusion which might likewise be deduced from the very small duration of the usual charge in the prime conductor.

With regard to the curious fact of the spontaneous explosion of a clean jar; which, when damped by breathing into it, was found much more capable of retaining its charge, there appears to be some difficulty in the theory. I have mentioned my supposition that Mr. Brook's experiment of soiling the jar with the hand, might have succeeded from the perspirable matter having operated as a varnish to the expulsion of moisture from the air. Mr. Cuthbertson's experiment overthrows this notion. I am now inclined to think that it depends upon undulation. The bare surface of clean glass may become charged in successive zones of the contrary electricities, as Priestley and others have shewn. When these zones have acquired the requisite intensity, they may explode into each other, and produce an undulation in the whole charge, which may greatly favour its flight through the interval from coating to coating. But when the surface is covered with distinct insulated particles of moisture, the escape from particle to particle must be by smaller leaps; the tranquillity of the charge will be scarcely at all disturbed; and the spontaneous explosion will not take place until the intensity has become so great, as to carry it through a space equal to the sum of the intervals between any one row of particles which form a line from coating to coating.

## V.

### *A short Mineralogical Description of the Mountain of Gibraltar.* By Major IMRIE.

[Concluded from Page 187, Vol. II.]

AT no great distance from where these crystals are found, upon the same slope of the mountain, but rather nearer to the level of the sea, a stratum of argillaceous matter has been laid open, divided into many thin beds, the broadest of which does not exceed a foot in thickness. Its general colour is of a whitish grey, with a small mixture of yellow; and it is divided transversely by straight septa or cracks, both sides of which are covered with dendritical figures of a yellowish brown colour, beautifully representing the objects of landscape. At the western base of the mountain, on a level with the sea, by which it is washed, a very extensive stratum occurs of the same nature as the last described, bearing from north to south, parallel with and dipping towards the mountain nearly at an angle of 40 degrees.

In some parts of the western slope of the mountain, towards the south, are found nests of a dark red shivery clay, in which are imbedded flints of a dirty sap green colour: of those no regular stratum is to be perceived; many of them are unshapely masses; but they in general

ral tend to the rhomboidal form, and are from three to four inches long by two or three broad, and an inch and a half thick. They are not incrufted as the flints found in chalk, nor have they the appearance of having been worn by attrition.

Upon different parts of the mountain, towards its bafe, are found large quantities of fand compofed of different materials, and affuming various appearances as to colour. The largeft bank of this arenaceous matter is upon the weftern fide of the mountain, and confifts of fmall particles of cryftallized quartz, colourlefs, and perfectly tranfparent per fe, but of an ochreous colour in the mafs on account of a red argillaceous earth which adheres to them. The fand of this bank is perfectly loofe and uncombined: one half of it has been levelled into an extenfive parade, its furface having been combined by the lime and rubbifh from the ruins of the town. The fouthern extremity of the bank is ftill to be feen in its natural ftate, and forms the burying-ground of the garrifon.

Upon the eaft fide of the mountain is found another of thefe banks, of confiderable extent, and, as I mentioned before, rifing from the Mediterranean in a rapid acclivity, and reaching to one-third of its entire elevation. This bank is compofed of fmall particles of cryftallized quartz, of teftaceous bodies rounded by attrition, and of a few minute particles of the calcareous rock; the whole has a whitifh grey colour. The rain-water which falls from the bare mountain rock above the fand brings along with it calcareous matter, which is depofited upon the bank, and combines its furface into a cruft, which in fome places is fo much indurated as to bear the preffure of the foot.

In other parts of the mountain where this fand is furrounded by the calcareous rock, and covered in and protected from the action of the air and corrofion of fea-falts, it is found in a perfect indurated ftate, combined by ftalactitical fpar, and forming a minute breccia. A quarry of this arenaceous ftone has been opened upon the fouth-eaft quarter of the mountain, and is made ufe of with great propriety to line the embrafures of fome of the new works belonging to the garrifon. Its inaptitude to fly off in fplinters when ftruck by a ball gives, in fuch fituations, additional fafety to the defenders of the place.

The weftern fide of the mountain's bafe around Rofia Bay, and the New Mole, is a rock compofed of an aggregate of fmall fragments of every foffil that has been here defcribed, with the addition of two different fpecies of marble, that are probably adventitious, as their native beds have not been found in the mountain. The one of thofe is black, and the other of an olive green colour. The whole of this mixture produces a moft beautiful breccia, and is firmly combined by a calcareous cement of a yellow verging towards an orange colour. It is fufceptible of a high polifh, except where fragments of the argillaceous ftrata occur: thefe can be eafily fmoothed down, but cannot be brought to a perfect polifh. The fragments in this breccia are angular, and none of them have the appearance of being water-worn.

It only now remains for me to mention, what are generally called the foffil bones found in the rock of Gibraltar. Thefe have been much talked of, and by fome looked upon as a phenomenon beyond the power of explanation. The general idea which exifts concerning them is, that they are found in a petrified ftate and inclofed in the folid calcareous rock; but thefe are miftakes which could only arife from inaccurate obfervation and falfe defcription.

In the perpendicular fiffures of the rock, and in fome of the caverns of the mountain (all of which afford evident proofs of their former communication with the furface), a calcareous

concretion

concretion is found of a reddish brown ferruginous colour, with an earthy fracture and considerable induration, inclosing the bones of various animals, some of which have the appearance of being human. These bones are of various sizes, and lie in all directions intermixed with shells of snails, fragments of the calcareous rock, and particles of spar; all of which materials are still to be seen in their natural uncombined states, partially scattered over the surface of the mountain. These having been swept by heavy rains at different periods from the surface into the situations above described, and having remained for a long series of years in those places of rest, exposed to the permeating action of water, have become enveloped in, and cemented by, the calcareous matter which it deposits.

The bones in this composition have not the smallest appearance of being petrified; and if they have undergone any change, it is more like that of calcination than that of petrifaction, as the most solid parts of them generally admit of being cut and scraped down with the same ease as chalk.

Bones combined in such concretions are not peculiar to Gibraltar: they are found in such large quantities in the country of Dalmatia, and upon its coasts in the islands of Cherso and Osero, that some naturalists have been induced to go so far as to assert, that there has been a regular stratum of such matter in that country, and that its present broken and interrupted appearance has been caused by earthquakes or other convulsions experienced in that part of the globe. But of late years, a traveller (Abbé Alberto Fortis) has given a minute description of the concretion in which the bones are found in that country: and by his account it appears, that with regard to situation, composition, and colour, it is perfectly similar to that found at Gibraltar. By his description it also appears that the two mountain rocks of Gibraltar and Dalmatia consist of the same species of calcareous stone; from which it is to be presumed that the concretions in both have been formed in the same manner and about the same periods.

Perhaps, if the fissures and caves of the rock of Dalmatia were still more minutely examined, their former communications with the surface might yet be traced, as in those described above; and in that case, there would be at least a strong probability that the materials of the concretions of that country have been brought together by the same accidental cause, which in my opinion has collected those found in the caverns of Gibraltar. I have traced in Gibraltar this concretion, from the lowest part of a deep perpendicular fissure up to the surface of the mountain. As it approached to the surface, the concretion became less firmly combined; and when it had no covering of the calcareous rock, a small degree of adhesion only remained, which was evidently produced by the argillaceous earth in its composition having been moistened by rain and baked by the sun.

The depth at which these materials had been penetrated by that proportion of stalactitical matter, capable of giving to the concretion its greatest adhesion and solidity, I found to vary according to its situation, and to the quantity of matter to be combined. In fissures narrow and contracted, I found the concretion possessing a great degree of hardness at six feet from the surface; but in other situations more extended, and where a larger quantity of the materials had been accumulated, I found it had not gained its greatest degree of adhesion at double that depth. In one of the caves where the mass of concretion is of considerable size, I perceived it to be divided into different beds, each bed being covered with a crust of the stalactitical spar from one inch to an inch and a half in thickness; which seems to indicate, that

that the materials had been carried in at various periods, and that thoſe periods have been very remote from each other.

At Roſia Bay, upon the weſt ſide of Gibraltar, this concretion is found in what has evidently been a cavern, originally formed by huge unſhapely maſſes of rock, which have tumbled in together. The fiſſure or cavern formed by the diſruption and ſubſidence of thoſe maſſes has been entirely filled up with the concretion, and is now expoſed to full view by the outward maſs having dropped down in conſequence of the encroachments of the ſea. It is to this ſpot that ſtrangers are generally led to examine the phenomenon; and the compoſition having here attained to its greateſt degree of hardneſs and ſolidity, the haſty obſerver, ſeeing the bones encloſed in what has ſo little the appearance of having been a vacuity, examines no farther, but immediately adopts the idea of their being incaſed in the ſolid rock. The communication from this former chaſm to the ſurface, from which it has received the materials of the concretion, is ſtill to be traced in the face of the rock; but its opening is at preſent covered by the baſe of the line wall of the garriſon. Here bones are found that are apparently human; and thoſe of them that appear to be of the legs, arms, and vertebræ of the back, are ſcattered among others of various kinds and ſizes, even down to the ſmalleſt bones of ſmall birds. I found here the complete jaw-bone of a ſheep; it contained its full complement of teeth, the enamel of which was perfect, and its whiteneſs and luſtre in no degree impaired. In the hollow parts of ſome of the large bones was contained a minute cryſtallization of pure and colourleſs calcareous ſpar; but in moſt the interior part conſiſted of a ſparry cruſt of a reddiſh colour, ſcarcely in any degree tranſparent.

At the northern extremity of the mountain the concretion is generally found in perpendicular fiſſures. The miners there employed upon the fortifications, in excavating one of thoſe fiſſures, found, at a great depth from the ſurface, two ſkulls, which were ſuppoſed to be human; but to me one of them, if not both, appeared to be too ſmall for the human ſpecies. The bone of each was perfectly firm and ſolid; from which it is to be preſumed that they were in a ſtate of maturity before they were encloſed in the concretion. Had they appertained to very young children, perhaps the bone would have been more porous, and of a leſs firm texture. The probability is, that they belonged to a ſpecies of monkey which ſtill continues to inhabit in conſiderable numbers thoſe parts of the rock which are to us inacceſſible.

This concretion varies in its compoſition according to the ſituation in which it is found. At the extremity of the Prince's lines, high in the rock which looks towards Spain, it is found to conſiſt only of a reddiſh calcareous earth, and the bones of ſmall birds cemented thereby. The rock around this ſpot is inhabited by a number of hawks, that in the breeding ſeaſon neſtle here and rear their young: the bones in this concretion are probably the remains of the food of thoſe birds. At the baſe of the rock below King's lines the concretion conſiſts of pebbles of the prevailing calcareous rock. In this concretion, at a very conſiderable depth under the ſurface, was found the under part of a glaſs bottle, uncommonly ſhaped, and of great thickneſs; the colour of the glaſs was of a dark green.

In many parts of the rock I have found concretions in which there are no bones of any kind; and on the elevated parts of the mountain, where the ſlopes are rapid, I have found a breccia (if I may ſo call it) entirely conſiſting of ſnail-ſhells combined in a maſs of opaque ſtalactitical ſpar of a yellowiſh brown colour. The various progreſſive augmentations of this

matter

matter were to be traced in various shades of the same colour, which, like the zones of the antique alabaster, curve round and follow the form of the shell. The purer matter of this spar has penetrated the shells, and in their interior hollows has formed a lining of small crystals, generally colourless, and perfectly transparent.

I have bestowed more time in endeavouring to describe the composition and the real situation in this concretion of bones than the subject, in the estimation of many, will seem to deserve, and, indeed, more than it deserves in my own opinion; but where an erroneous opinion has obtained a footing in consequence of inaccurate observations and partial description, it is the duty of every new observer to endeavour to correct it.

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## VI.

### *Accounts of the Discovery of Native Gold in Ireland.*

THE public attention was a few years ago greatly excited by the important mineralogical discovery of native gold in Ireland; soon after which accounts were sent to the Royal Society. (Phil. Transf. 1796.) It may easily be imagined, that these works must have been suspended by the convulsions which at present agitate that unhappy kingdom. But as I hope by enquiry to ascertain what has been done since the original discovery, which from its interest and curiosity is highly deserving of attention, I shall here present the substance of these accounts to my readers with very little abridgement.

John Lloyd, Esq. of Havodynos, gave the following account, dated November the 4th, 1795:

About seven miles westward of Arklow, in the county of Wicklow, there is a very high hill, perhaps six or seven hundred yards above the sea, called Croughan Kinshelly, one of whose N. E. abutments or buttresses is called Balinnagore, to which the ascent may be made in half or three quarters of an hour. In Jacob Nevill's map of the county of Wicklow, published in 1760, by casting your eye on the river Ovo, which runs by Arklow, at about four miles above the latter place, you will perceive the conflux of two considerable streams, and of a third about half a mile higher up, close to a bridge. By tracing this last to its source, you will come to a place set down in the map Ballinvally; this is a ravine between two others, that run down the side of the hill into a semi-circle, or more properly semi-elliptical valley, which extends in breadth from one summit to the other of the boundary of the valley, and across the valley three quarters of a mile or somewhat less. The hollow side of the hill forms the termination of the valley, and down which run the three ravines abovementioned. At their junction the brook assumes the name of Ballinaslogo: at this place the descent is not very rapid, and so continues a hanging level for about a quarter of a mile or somewhat more, when the valley grows narrower and the sides of the brook become steeper; and it should seem that some rocky bars across the course of the brook have formed the gravelly beds, above, over, and through which the stream flows, and in which the gold is found. The bed of the brook, and the adjacent banks of gravel on each side, for near a quarter of a mile in length, and for 20 or 30 yards in breadth, have been entirely stirred and washed by the peasants of the country, who amounted to many hundreds at work at a time whilst they were permitted to search for the metal.

A gentleman who ſaw them at work aſſured Mr. Lloyd, that he counted above three hundred women at one time, beſides great numbers of men and children.

The ſtream runs down to the N. E. from the hill, which ſeems to conſiſt of a maſs of ſhiſtus and quartz; for, on examination of the principal ravine, which is now waſhed clean by the late heavy rains, the bottom conſiſted of ſhiſtus interſected at different diſtances and in various places by veins of quartz, and of which ſubſtances the gravelly beds at the bottom, where the gold is found, ſeem to conſiſt.

Large tumblers of quartz are thickly ſcattered over the ſurface of the top of the hill, under a turbary of conſiderable thickneſs, upon the removal of which theſe tumblers appear.

The gold has been found in maſſes of all ſizes, from thoſe of ſmall grains to that of a piece of the weight of five ounces; which beautiful ſpecimen is intended for the cabinet of a nobleman adored in this country, and not leſs reſpected by his friends in England, and which I dare to ſay you will ſhortly have an opportunity of ſeeing in London. One piece of twenty-two ounces has been taken up, and which I am told is to be preſented to his Majeſty.

Mr. Graham of Ballycoage informed Mr. Lloyd, that about twenty-five years ago, or more, one Dunaghoo a ſchoolmaſter, reſident near the place, uſed frequently to entertain them with accounts of the richneſs of the valley in gold; and that this man uſed to go in the night and break of day to ſearch for the treaſure; and theſe gentlemen with their ſchool-fellows uſed to watch the old man in his excurſions to the hill, to frighten him, deeming him to be deranged in his intellects. However, the idea of this treaſure did at laſt actually derange him.

Mr. Lloyd learned alſo from John Byrne, that about eleven or twelve years ago, when he was a boy, he was fiſhing in this brook, and found a piece of gold of a quarter of an ounce, which was ſold in Dublin; but that, upon one of his brothers telling him it muſt have been dropped into the brook by accident, he gave over all thoughts of ſearching for more. Charles Toole, a miner at Cronbane, ſaid, that he heard of this diſcovery at the time, but gave no credit to it, as he never found any gold, and lives very near the place; and Mr. Lloyd was alſo credibly informed, that a goldſmith in Dublin has every year for eleven or twelve years bought four or five ounces of gold brought conſtantly by the ſame perſon, but not John Byrne.

The name of the brook where the gold is found is in Iriſh Aughatinavought.

The account of the mineralogy and other circumſtances by Abraham Mills, Eſq. is as follows:

The workings, which the peaſantry recently undertook, are on the north-eaſt ſide of the mountain Croughan Kinſhelly, within the barony of Arklow and county of Wicklow, on the lands of the Earl of Caryſfort, wherein the Earl of Ormond claims a right to the minerals, in conſequence of a grant in the reign of King Henry the Second by Prince John, during his command of his father's forces in Ireland; which grant was renewed and confirmed by Queen Elizabeth, and again by King Charles the Second *.

The ſummit of the mountain is the boundary between the counties of Wicklow and Wexford; ſeven Engliſh miles weſt from Arklow, ten to the ſouth-weſtward of Rathdrum, and ſix ſouth-weſterly from Cronbane mines; by eſtimation about ſix hundred yards above

* It was afterwards found that this grant had been annulled by an act of the Iriſh Parliament near the beginning of the preſent century. Mr. Mills has ſince worked this mine on account of Government. N.

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the level of the sea. It extends W. by N. and E. by S. and stretches away to the north-eastward to Ballycoage, where shafts have formerly been sunk, and some copper and magnetic iron ore has been found; and thence to the N. E. where extends a tract of mineral country eight miles in length, running through the lands of Ballymurtagh, Ballygahan, Tigrony, Cronebane, Connery, and Kilmacoe, in all which veins of copper ore are found; and terminating at the slate quarry at Balnabarny.

On the highest part of the mountain are bare rocks, being a variety of argillite *, whose joints range N. N. E. and S. S. W. hade to the S. S. W. and in one part include a rib of quartz three inches wide, which follows the direction of the strata. Around the rocks for some distance, is sound ground, covered with heath; descending to the eastward there is springy ground abounding with coarse grass; and below that a very extensive bog, in which the turf is from four to nine feet thick, and beneath it in the substratum of clay are many angular fragments of quartz, containing chlorite and ferruginous earth. Below the turbary the ground falls with a quick descent, and three ravines are observed. The central one, which is the most considerable, has been worn by torrents, which derive their source from the bog; the others are formed lower down the mountain by springs, which uniting with the former, below their junction the gold has been found. The smaller have not water sufficient to wash away the incumbent clay so as to lay bare the substratum; and their beds only contain gravel consisting of quartz, with chlorite and other substances of which the mountain consists. The great ravine presents a most interesting aspect; the water in its descent has in a very short distance from the bog entirely carried off the clay, and considerably worn down the substrata of rock, which it has laid open to inspection.

Descending along the bed of the great ravine, whose general course is to the eastward, a yellow argillaceous shistus is first seen; the laminæ are much shattered, are very thin, have a slight hade to the S. S. W. range E. S. E and W. N. W. Included within the shist is a vein of compact barren quartz, about three feet wide, ranging N. E. and S. W.; below this is another vein about nine inches wide, having the same range as the former, and hading to the northward, consisting of quartz including ferruginous earth. Lower down is a vein of a compact aggregate substance, apparently compounded of quartz, ochraceous earth, chert, minute particles of mica, and some little argillite of unknown breadth, ranging E. and W. hading fast to the southward, and including strings of quartz from one to two inches thick, the quartz containing ferruginous earth. The yellow argillaceous shistus is again seen with its former hade and range; and then adjacent to a quartz vein is laminated blue argillaceous shistus, ranging N. E. and S. W. and hading S. E.; which is afterwards seen varying its range and hade, running E. N. E. and W. S. W. and hading N. N. W. Lower down, the blue shist is observed more compact, though still laminated. The ground, less steep, becomes springy, is inclosed, and the ravine, shallower, has deposited a considerable quantity of clay-sand and gravel. Following the course of the ravine, or, as it may now more properly be called, the brook, you arrive at the road which leads to Arklow; here is a ford, and the brook has the Irish name of Aughatinavought (the river that drowned the old man): hence it descends to the Aughrim river, just above its confluence with that from Rathdrum, which after their junction take the general name of the

* Kirwan, edit. 1794, p. 234.

Ovo, that, discharging itself into the sea near the town of Arklow, forms an harbour for vessels of small burthen.

The lands of Ballinvally are to the southward, and the lands of Ballinagore to the northward of the ford, where the blue shistus rock, whose joints are nearly vertical, is seen ranging E. N. E. and W. S. W. including small strings of quartz which contain ferruginous earth. The same kind of earth is also seen in the quartz, contained in a vein from ten to twelve inches wide, ranging E. N. E. and W. S. W. and hading to the southward, which has been laid open in forming the Arklow road.

There the valley is from twenty to thirty yards in width, and is covered with substances washed down from the mountain, which on the sides have accumulated to the depth of about twelve feet. A thin stratum of vegetable soil lies uppermost; then clay mingled with fine sand composed of small particles of quartz, mica, and shist; beneath which the same substances are larger, and constitute a bed of gravel that also contains nodules of fine grained iron-stone, which produces 50 per cent. of crude iron: incumbent on the rock are large tumblers of quartz, a variety of argillite and shistus; many pieces of the quartz are perfectly pure; others are attached to the shistus; others contain chlorite, pyrites, mica, and ferruginous earth; and the arsenical cubical pyrites frequently occurs imbedded in the blue shistus. In this mass of matter, before the workings began, the brook had formed its channel down to the surface of the rock, and between six and seven feet wide, but in times of floods extended itself entirely over the valley.

Researches have been made for the gold amidst the sand and the gravel along the run of the brook for near half a mile in length; but it is only about one hundred and fifty yards above, and about two hundred yards below the ford, that the trials have been attended with much success: within that space the valley is tolerably level, and the banks of the brook have not more than five feet of sand and gravel above the rock: added to this, it takes a small turn to the southward, and consequently the rude surfaces of the shistus rock in some degree cross its course, and form natural impediments to the particles of gold being carried further down the stream, which still lower has a more rapid descent. Besides, the rude manner in which the country people worked seldom enabled them to penetrate to the rock in those places where the sand and gravel were of any material depth. Their method was to turn the course of the water wherever they deemed necessary, and then with any instruments they could procure to dig holes down to the rock, and, by washing in bowls and sieves the sand and gravel they threw out, to separate the particles of gold which it contained; and from the slovenly and hasty way in which their operations were performed, much gold most probably escaped their search: and that indeed actually appears to have been the case; for, since the late rains washed the clay and gravel which had been thrown up, gold has been found lying on the surface. The situation of the place, and the constant command of water, do however very clearly point out the great facility with which the gold might be separated from the trash, by adopting the mode of working practised at the best tin stream works in the county of Cornwall; that is, entirely to remove (by machinery) the whole cover off the rock, and then wash it in proper buddles and sieves. And by thus continuing the operations, constantly advancing in the ravine towards the mountain, as long as gold should be found, the vein that forms its matrix might probably be laid bare.

The discovery was made public, and the workings began early in the month of September

last,

laſt (1795), and continued till the 18th of October, when a party of the Kildare militia arrived, and took poſſeſſion by order of government; and the great concourſe of people, who were buſily engaged in endeavouring to procure a ſhare of the treaſure, immediately deſiſted from their labour, and peaceably retired.

Calculations have been made, that, during the foregoing period, gold to the amount of three thouſand pounds Iriſh ſterling was ſold to various perſons; the average price was three pounds fifteen ſhillings per ounce; hence eight hundred ounces appear to have been collected within the ſhort ſpace of ſix weeks.

The gold is of a bright yellow, perfectly malleable; the ſpecific gravity of an apparently clean piece 19,000. A ſpecimen aſſayed here by Mr. Weaver in the moiſt way produced from 24 grains, $22\frac{58}{101}$ grains of pure gold, and $1\frac{43}{101}$ of ſilver. Some of the gold is intimately blended with, and adherent to quartz; ſome (it is ſaid) was found united to the fine-grained iron-ſtone, but the major part was entirely free from the matrix; every piece more or leſs rounded on the edges, of various weights, forms and ſizes, from the moſt minute particle up to 2 oz. 17 dwt.; only two pieces are known to have been found of ſuperior weight, and one of thoſe is five and the other twenty-two ounces.

The bearings are all taken by the compaſs, without allowing for the variation.

William Moleſworth, Eſq. of Dublin, in a letter to Richard Moleſworth, Eſq. F. R. S. writes, that he weighed the largeſt piece of gold in his balance, both in air and water, and that its weight was 20 oz. 2 dwt. 21 gr. and its ſpecific gravity to that of ſterling gold, as 12 to 18. Alſo, that Richard Kirwan, Eſq. F. R. S. found the ſpecific gravity of another ſpecimen to be as 13 to 18. Hence, as the gold was worth 4l. an ounce, Mr. William Moleſworth concludes that the ſpecimens are full of pores and cavities which increaſe their bulk, and that there are ſome extraneous ſubſtances, ſuch as dirt or clay, contained in thoſe cavities.

This opinion was diſcovered to be well founded, by cutting through ſome of the ſmall lumps.

Staneſby Alchorne, Eſq. his Majeſty's aſſay-maſter at the Tower of London, aſſayed two ſpecimens of this native gold. The firſt appeared to contain in 24 carats,

$21\frac{6}{8}$ of fine gold.
$1\frac{7}{8}$ of fine ſilver.
$\frac{3}{8}$ of alloy, which ſeemed to be copper tinged with a little iron.

The ſecond ſpecimen differed only in holding $21\frac{5}{8}$ inſtead of $21\frac{6}{8}$ of fine gold.

Major John Brown, of the royal engineers, tranſmitted to the Right Hon. Thomas Pelham a ſketch of the ſpot where the gold was found, which Mr. Pelham permitted to be engraved for the uſe of the Royal Society, and of which fig. 5. plate IX. is a copy, one third of the ſize of the original.

## VII.

*An Account of the Principles and Effect of Steam Engines, which act by means of a Piston. With Descriptions of the Atmospherical Engine of* NEWCOMEN *and* CAWLEY; *the Engine of* WATT, *which works in Vacuo; and a new Engine by* Mr. SADLER, *in which the direct Action of Steam and the Pressure of the Atmosphere are combined.*

SOME account of the original steam-engine of the Marquis of Worcester, and its subsequent improvements, has been given in a former paper in this work *. One of the chief imperfections of that engine was then shewn to consist in the direct action of the steam, for forcing, being necessarily more than equal to the weight of the column of water required to be raised; in consequence of which, it became in most cases an indispensable condition, that the boiler and vessels should be very strong, as well as that a large quantity of fuel should be consumed, to produce steam sufficiently dense. It is probable that these inconveniences may have early directed the thoughts of various ingenious men to the application of a piston, though the difficulties of the undertaking seem to have retarded this pursuit for a considerable time. The first steam-engine, with a piston, made in 1707 by Papin †, was little calculated to remove these difficulties; and it is to Newcomen and Cawley that we are indebted for the application of a piston with machinery, by which the indirect action of steam little stronger than the atmosphere, or rather the direct action of the atmosphere, is made to act with safety and effect against the most severe pressures. It appears that they had brought their engine, about the year 1713 ‡, to a degree of perfection little different from those which are to be seen at present. A particular description of this engine, with drawings of its parts, and a considerable portion of the history of its invention, are to be met with in Desaguliers's Course of Experimental Philosophy, and it has also been described in many other books. For these reasons, I shall in this place give merely a verbal account of its principles and mode of operation.

Suppose a very large syringe to be set upright, and a piston or plug inserted at the upper end, the usual aperture being supposed to be at the lower extremity. If this last aperture be open, the piston will descend by its own weight, neglecting the effect of friction at its circumference. But let it be imagined, that the piston is supported by a counter-weight at the opposite extremity, by a lever or by any other means. In this case the piston will not descend unless more weight be added to it. Among the various ways of applying such a weight, there is one which consists in exhausting the air from the internal part of the cylinder beneath the piston. For, if this were done, it is evident that the whole pressure of the atmosphere, which amounts to about twelve pounds on every circular inch, will become active upon the upper surface. If the vacuum were to be produced by means of an air-pump, it may easily be allowed, that the labour of effecting it would be at least equal to that of any work which might be performed by the subsequent descent of the piston. We have seen that, in Savery's engine, the operation of steam is twofold; namely, by the direct pressure from its

* Philosophical Journal, I. 419.

† Loco citato. p. 421.

‡ Desaguliers in his Lectures, ii. 467, says that it had been in use near thirty years at the time he wrote, and the imprimatur to his work bears date November 17, 1743. See also p. 532 of the same volume

elasticity,

elasticity, and by the indirect consequence of its condensation, which affords a vacuum. This last is the only principle displayed in Newcomen's engine. In order to produce the vacuum at pleasure, it becomes requisite that various apertures should be formed at the bottom of the cylinder or syringe we have been speaking of:—one to communicate steam from a boiler; another to admit a jet of cold water, to condense that steam during the interval in which the communication from the boiler is cut off; a third provided with a pipe called the eduction-pipe, to carry off the condensed steam and injection water; and lastly, a small lateral aperture or valve through which the permanently elastic fluid, which cannot descend through the eduction-pipe, may be driven out. This last is called the snifting clack. By these provisions the operation is made to take place as follows: The piston being up, the steam-cock is opened and steam issues from the boiler, which being less than half the weight of common air, rises to the top and expels the air through the eduction-pipe, of which the lower extremity is covered with a flap valve in a trough of water. When the noise of its escape is heard the steam-cock is shut, and the injection-pipe being opened throws a stream of cold water against the bottom of the piston. The steam becomes immediately condensed, and the pressure of the atmosphere forces the piston down into the vacuum. Upon its progress downwards the injection-pipe is closed; and when it has arrived nearly to the bottom of the cylinder, the steam-cock is again opened. The elastic steam then not only fills the small space between the cylinder and the bottom, but its pressure assists the eduction water to pass off through its pipe, and drives the disengaged elastic fluid through the snift. In this state therefore the steam is somewhat stronger than the atmosphere, and counterpoises its action on the upper surface of the piston; whence the piston itself rises by the action of the counter-weight, and regains its original position at the top of the cylinder. A second repetition of the process, namely, of shutting off the steam and injecting cold water, causes it again to descend, and in this manner the alternations may be continued without limit.

As the pressure requisite to work an engine of this kind with speed, and to overcome the friction of its parts, may be estimated at about $7\frac{1}{2}$ pounds for every round inch, the effect of a piston three feet in diameter, with ten strokes of six feet each per moment, will be to raise a weight of near half a ton at the rate of one foot per second. Such a power will therefore be very considerable.

It is to be understood, that the opening and shutting of the steam and injection cocks are performed by apparatus fixed to the working beam, in such a manner as to strike the levers of those cocks at the precise instants of time when their effects are required to be produced. The attendant has no other office to perform than keeping up the fire.

This curious and most eminently useful engine became an object of the researches of James Watt, then of Glasgow, but since associated with Matthew Boulton of Birmingham. It would be superfluous for me to enter into any general account of the science and intelligence of either of these engineers, or of the great advantages which society must ever derive when the spirit of enterprise is joined to the exertions of mental ability. Neither can I here attempt to detail the variety of new results which are exhibited in the specifications lodged by Watt in the Chancery offices concerning this object. My present limits and the attention which the world has already paid to these eminent men, and the products of their enlightened

lightened activity, render both unneceſſary. I ſhall therefore confine myſelf to remark, that the great features of improvement made in the engine of Newcomen by Watt are, firſt, that the elaſticity of the ſteam itſelf is uſed as the active power in his engine; and ſecondly, that beſides various other judicious arrangements for the economy of heat, he condenſes the ſteam, not in the cylinder, but in a ſeparate veſſel.

In the great cylinder or ſyringe, concerning which we have ſpoken, in deſcribing the engine of Newcomen, let us ſuppoſe the upper part to be cloſed, and the piſton-rod to ſlide air-tight through a collar of leathers. In this ſituation, it is evident, that the piſton might be depreſſed by throwing the ſteam upon its upper ſurface, through an aperture at the ſuperior end of the cylinder. But if we ſuppoſe the external air to have acceſs to the lower ſurface of the piſton, we ſhall find, that ſteam no ſtronger in its elaſticity than to equal the weight of the atmoſphere would not move the piſton at all; and conſequently that this new engine would require much denſer ſteam, and conſume much more fuel than the old engine. The remedy for this evil is to maintain a conſtant vacuum beneath the piſton. If ſuch a vacuum were originally produced by ſteam, it is certain that its permanency could not be depended on, unleſs the engine contained a proviſion for conſtantly keeping it up. Mr. Watt's contrivance in his ſimpleſt engine is as follows: The ſteam is conveyed from the boiler to the upper part of the cylinder through a pipe, which alſo communicates occaſionally with the lower part, and beyond that ſpace with a veſſel immerſed in a trough of water; in which veſſel the condenſation is performed by an injected ſtream of cold water. This water is drawn off, not by an eduction-pipe but by a pump, of which the ſtroke is ſufficiently capacious to leave room for the elaſtic fluid, ſeparated during the injection, to follow and be carried out with the injection water. Suppoſe now the piſton to be at its greateſt elevation, and the communication from the boiler to the upper as well as to the lower parts of the cylinder to be opened. The ſteam will then paſs into the whole internal part of the engine, and will drive the air downwards into the condenſer, and thence through the valves of the air-pump. In this ſituation, if the communication from the boiler to the lower part of the cylinder be ſtopped, and an injection be made into the condenſer, a vacuum will be produced in that veſſel, and the ſteam contained in the lower part of the cylinder and communication pipe will expand itſelf with wonderful rapidity towards the condenſer, ſo that in a period of time too minute to be appretiated, the whole of the ſteam beneath the piſton will be practically condenſed. The ſteam which continues to act above the piſton will immediately depreſs it into the vacuum beneath; at the ſame time that by connection with the external apparatus the piſton of the air-pump alſo deſcends in its barrel. When the ſtroke is nearly completed downwards, the requiſite part of the apparatus ſhuts the communication with the boiler; opens that between the upper and lower parts of the cylinder and condenſing veſſel; and turns the injection-cock. At this very inſtant the piſton loſes its tendency to deſcend, becauſe the ſteam preſſes equally on both ſurfaces, and continues its equality of preſſure while the condenſation is performed. It therefore riſes; the injection is ſtopped; and the air-pump making its ſtroke ſuffers the injection water and a conſiderable part of the elaſtic fluid to paſs through its lower valve. The vacuum is thus kept up through the whole internal capacity of the engine. As ſoon as the piſton has reached the upper part of the cylinder, the communication to the under part of the cylinder is ſtopped, and that with

the boiler opened as before; the consequence of which is, that the piston again descends, and in this manner the alternations repeatedly take place.

The principal augmentation of power in this engine, compared with that of Newcomen, appears to arise from the cylinder not being cooled by the injection water, and its being practicable to use steam somewhat stronger than the pressure of the atmosphere. In general these engines are worked by steam, which would support a column of four or five inches of mercury besides the pressure of the atmosphere, and I have sometimes seen the gage as high as eight inches. But whether the comparative profit of the additional work was such as to repay the extraordinary consumption of fuel in such cases may be doubted; and indeed I suppose this practice is never adopted but when the work of a manufactory is such as to exceed the power or rate of the engine constructed for performing it.

The most ample information respecting these improved steam engines, which is to be met with in print, is found in the Nouvelle Architecture Hydraulique of Prony.

When we contemplate these engines together with the simpler engine of Savery, one of the most striking differences, is, that the latter is not embarrassed with the weight and expence of the beam and counterpoise. I believe that the fly was first introduced by Messrs. Watt and Boulton, as an equalizer of the action in steam engines, which in various constructions renders a counterpoise unnecessary, but is said to diminish the power by loading the work with friction and resistance. Of this however I can say nothing from my own experience or observation. The counterpoise is also unnecessary in the engines called double engines, in which the steam is made to act alternately on each side of the piston, by proper communication from the boiler, while the space into which the piston is to move is made to communicate with the condensing vessel, where a constant injection is maintained. I was also informed, in the year 1794, that some engines had been constructed without the beam; but the architect from whom I had the information did not state the particulars.

The injection water and elastic fluid are disposed of in Newcomen's engine with scarcely any loss of power, because the former flows spontaneously through the eduction-pipe, and the latter is driven out by a very slight effort of the steam against the atmosphere. Watt's engine could not have an eduction-pipe unless the column were at least 34 or 35 feet long, to exclude the atmosphere, and even in that case there could be no shift to deliver the elastic fluid. It was therefore necessary there should be an air-pump to carry off both; and this is a load upon the engine equal to the amount of the friction of these additional parts and the whole weight of the eduction water. I am not well informed of this last quantity; but suppose it to be about one eightieth * part of the power of the engine.

The steam-engine for which a patent has lately been granted to Mr. Sadler, is worked without a lever or beam, and consequently has not the inertia of that heavy mass to overcome. The greatest part of its action is performed by the elasticity of steam; but the most remarkable character of his invention is, that part of the steam previous to its condensation is employed a second time in another cylinder, the piston of which is subject to the pressure of the atmosphere. By this second application it not only performs the office of an air-pump in a very accurate manner, but likewise adds to the total amount of force in the machine.

* Supposing the injection water to be about $\frac{1}{120}$ of the magnitude of the cylinder within, and that the stroke would raise $\frac{2}{3}$ of the same magnitude of water through its own length.

Plate X.

Plate X. exhibits a projection of part of this engine, the boiler and the working parts being left out. R S U T represent a frame of wood. A is the larger cylinder, of which the piston-rod is kept vertical by a wheel I, which runs between parallel plates with a very small degree of shake. The rise and fall of this wheel moves the arm N O of a crank, which drives the fly P Q, and gives motion to the pumps or other working parts. B is the second cylinder open at top, the piston-rod of which is kept vertical in like manner by a wheel K. A connection is formed between the two pistons by the lever L M, which causes them to make their strokes together. D is a valve in the piston of A, which, by means of its tail beneath, is opened when that piston is down, and continues so during the whole ascent, until it becomes again closed by the pressure of its crown against the top of the cylinder.

Suppose the pistons to be near the tops of their respective cylinders, and the valve D to be open: if C be opened, the steam will pass through the cylinder A, and enter B by the passage E, driving the air before it through the valve G. If then the valve D be closed by raising the piston or otherwise, and an injection of cold water be made through F into B, the steam in that cylinder and beneath the piston of A will be condensed, and both pistons will descend; that in A by the action of the steam, and that in B by the pressure of the atmosphere. Near the termination of this descent the valve D will be opened, and the piston in A will be left at liberty to rise, in consequence of the equal action of the steam on both sides, at the same time that, the valve C being shut, there will be no farther supply from the boiler. The steam which occupied the space above the piston in A will expand through E, and assist the rise of the piston in B. If we overlook the effect of refrigeration in the passage E, and against the piston at B, the steam will begin to act beneath this piston with a force not greatly different from its last action upon that in A. It would not be easy to calculate the whole effect of the steam in its second application, not only for want of an accurate statement of the elasticity of this fluid during its expansion; but because the practical effect of the temperature of the second cylinder in diminishing that force is still more difficult to be appretiated. I shall therefore only observe, that the piston in B having descended so as to touch the surface of the injection water, and the elastic fluid resting upon it, not only causes that air but a portion of the hot water to pass through the valve W, which it carries up and discharges through a conveyance at the upper part of the cylinder to feed the boiler. The steam which follows it through E, drives all the elastic fluid through the valve of that passage, whence it remains in B till the next stroke carries it off. The quantity of water which shall rise above the piston through W, may be regulated by the height of the external surface of the cistern into which the pipe G discharges itself. The excess of the action of the steam beneath the piston in B, beyond the weight of that piston and the water it carries, will be an acquisition to the power of the engine. When we consider the facts, we may observe, that, if B were too small, the action of the steam under its piston would approach more nearly to equality with the last action in A; but that the stroke would be insufficient to carry off the elastic fluid, and the addition to the force of the engine inconsiderable; and on the other hand, if it were too large, the greatest part of the rising stroke would be performed against the pressure of the atmosphere, with very little assistance from the expanded steam. Whence it follows, that there is a certain definite proportion under like circumstances of pressure, temperature and work, between the two cylinders, which will produce a greater effect than any other. To determine this would be the object of computation, if the data were at hand; but it is probable

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that an experimental result with regard to those dimensions might be obtained with as little trouble as the mere data for computation.

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## VIII.

### *On the supposed Improvement of Achromatic Lenses, when rendered more transparent by cementing them together.*

AN achromatic glass, consisting of one concave and two convex lenses, has six surfaces at which the reflexion of light can take place. Two evils of considerable magnitude are produced by this reflexion. The focal image becomes obscure from the loss of the light so diverted, and the ground or field of view is rendered misty by the irregular illumination afforded by part of this light, which enters the tube. These consequences are strikingly observed by holding an achromatic lens in such a manner as to throw the image of a window upon a sheet of paper, at the same time that a like image is afforded by a simple convex lens of the same focal length. The latter image will be bright and clear, while the former is very faint. As the reflexion of light is strongest at surfaces which confine mediums most different in density, it may naturally be imagined that the mischievous effect of the four surfaces, at which the lenses are applied to each other, might be in a great measure removed by the interposition of a denser fluid than air. * Many years ago the Abbé Rochon made some experiments to improve achromatic lenses by this invention, and Mr. Grateloup afterwards made use of a transparent solid for the same purpose. He took a very pure tear of mastic, and interposed a piece of sufficient magnitude between the lenses of an achromatic glass. These being immersed under water of which the temperature was gradually raised, the mastic at length became soft, and by pressure of the glasses was made to occupy the whole of the two spaces between the concave and the exterior lenses. After this process the compound lens was beautifully transparent; the reflected images could scarcely be discerned; and upon trial in its tube the telescope was found to be greatly improved.

My attention to this contrivance was excited by the approbation bestowed upon a telescope of this kind, of 27 inches long and 23 lines aperture, by Citizen Lalande, in the Connoissance de Tems for the fourth year of the French Republic, page 364. It appeared to me, as it certainly will to the reader, to be a matter of no small surprise, that an improvement

* Count Cassini, in the Memoirs of the Parisian Academy for 1787, p. 29, informs us, that a memoir *sur les moyens de perfectionner les lunettes achromatiques par l'interposition d'un fluide entre les objectifs*, by the Abbé Rochon, was read before that Academy in January 1774, and inserted in the Recueil des Memoires de Mechanique et de Physique, which I have not seen; and in a note on this passage he quotes the Report of the Commissioners of the Academy, who express their satisfaction at the result of their trials for correcting great part of the defects arising from the surfaces of the glasses by the interposition of a fluid between them, but recommend trials with the telescopes of astronomers on celestial objects; which it should therefore seem had not then been made. The same author proceeds to acquaint us, that Mr. Grateloup used mastic in 1785, after which the Sieur Putois made excellent lenses of this kind; and that the mastic answered well with compound lenses, whose interior surfaces were only ground (doucies) but not polished. In this last experiment, however, it can hardly be imagined that the lens would have supported an high power; because the mastic, though it might afford transparency, must have left the confines of the mediums as imperfect as before.

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of ſuch value ſhould never have been adopted in this kingdom. As it is no where ſaid that lenſes were conſtructed with a particular regard to the denſity and figure of the interpoſed maſtic; but there ſeems reaſon to conclude, that in every caſe an achromatic lens of the uſual conſtruction was ſtated to have been rendered more perfect by this treatment,—I thought it beſt to overlook the theoretical objections, and confine myſelf in the firſt inſtance to experiment and enquiry. For this purpoſe I took an achromatic lens, conſiſting of two convex lenſes, and one concave, of which the radii need not here be detailed. When together they formed a compound lens of $7\frac{3}{4}$ inches focus, with an aperture of nearly $1\frac{1}{2}$ inch, which, upon a rough trial with a magnifying power of 30 times, exhibited ſcarcely any colour. Upon filling the interſtices of this lens with water, the focal image became much brighter; but the focal diſtance was diminiſhed to ſomewhat leſs than ſix inches, and much colour was produced with as low a magnifying power as ten times. It is evident, therefore, that the lens was greatly injured by the expedient made uſe of to prevent the loſs by reflexion; and it may eaſily be inferred that a denſer ſubſtance, ſuch as maſtic, would have ſhortened its focus and diſturbed its compenſations in a ſtill greater degree.

Some time after making this experiment, I applied to the celebrated Mr. Ramſden, to whoſe unequalled ability and invention the arts of philoſophical obſervation are ſo highly indebted. I did not expect to receive any information tending to ſhew that a combination of lenſes, differing in curvature at the ſurfaces of appoſition and achromatic in the air, could retain the ſame property when either partially or totally immerſed in another tranſparent medium of different refractive or diſperſive power. My principal object was, to know whether the French philoſophers had conſtructed lenſes of ſix parts duly adapted to each other; that is to ſay, conſidering the two portions of maſtic as lenſes, and not merely as a medium to prevent loſs by reflexion. From him I learned that the ſuppoſed improvement had long ſince been communicated to him by ſome gentlemen of the Paris academy, who affirmed that an achromatic lens of Dollond's make had been much improved by the interpoſition of maſtic between its parts, at the ſame time that they aſſerted in general terms that the ſame might be done with any other object glaſs of this kind. He put a good object glaſs into their hands for this purpoſe. The experiment was made, and the reſult proved ſimilar to that which I have already related. The aberrations from figure as well as colour became very perceptible;—and in a word the lens, though much clearer, had loſt its moſt valuable qualities.

Such is the reſult of a proceſs which has been in the poſſeſſion of our learned neighbours for about four-and-twenty years, and is ſtill eſteemed by them; but which has never been adopted by our opticians:—a proceſs, the value of which, it ſhould appear, might be aſcertained in an inſtant by mere inſpection through the teleſcope in queſtion. We ſeem as if driven to the ſuppoſition that ſomething might yet remain unexplained. Has the miſchief of this proceſs been overlooked by men ſo acute and enlightened?—Or has it happened that the interior curvatures of the lenſes, on which they operated, were nearly parallel to each other; ſo that the addition of light (with the magnifying power commonly uſed with an index teleſcope) might be thought to offer an advantage, in angular obſervations, more than ſufficient to compenſate for the other defects?

IX. De-

## IX.

## *Deſcription of a very ſimple Apparatus for performing the great Experiment of producing Water by the Combuſtion of Hydrogen Gas. Invented by Mr.* JOHN CUTHBERTSON *.

A D B C, fig. 6, plate IX., repreſents the inſtrument ſtanding in a veſſel, a b c d, nearly filled with water.

A D is a large glaſs bottle, holding about 1000 cubic inches of water, mounted at the top with a braſs cap, which ſcrews off at A. The riſing part at the bottom is bored through and mounted with braſs, in which ſcrews a piece repreſented by a b, fig. 7, having a part at one end which fits into the hole, and the other end a ſhank with a ſcrew at the bottom. E F, fig. 6, is a ſtraight bar of braſs; B C are two glaſs receivers, mounted at the top with braſs, each having a ſhank which paſſes through the braſs bar, and by means of a female ſcrew is ſcrewed faſt to it: theſe mountings are perforated perpendicularly, and have alſo a ſide hole, which correſponds with a hole in the braſs bar, paſſing from the ſhank of each receiver; which hole alſo correſponds with two holes repreſented in fig. 7, communicating with the inſide of the large bottle. At L, M, in the braſs bar, are two air cocks, with holes drilled through them in ſuch a direction, that when the blades of the cocks ſtand lengthwiſe with the bar they correſpond with the holes in it. F R and E N are two ſtraight flat pieces of braſs; in each of them is a hole, through which paſs the ends of two ſcrews, that are ſcrewed faſt into the ſides of the veſſel containing the water, and confine the bars by means of two female ſcrews. O P is a long braſs wire, with a piece of platina wire at the end P: this wire is fixed to the mounting at the top of the bottle, and is bended ſo that the end P ſtands as near as poſſible, but not to touch the ſmall hole which paſſes through the piece a b, fig. 2.

When this inſtrument is to be uſed, the large glaſs muſt be firſt filled with oxygen gas (or common air when mere exhibition is intended): this may be done either by means of an air pump, or by filling it with water, inverting it and ſuffering the air to aſcend. When either of theſe operations is to be performed, it muſt firſt be detached from the receivers by unſcrewing the two female ſcrews Q Q. All the other parts remain annexed to it, and care muſt be taken that the two air-cocks are ſhut. When it is filled with the air required, it muſt be ſet upon the receivers, the mountings of which are marked, as well as the bar, and care muſt be taken that they are not miſplaced: the whole inſtrument muſt then be placed in the water veſſel, as is repreſented. The receiver B has a hole about the middle at t. This receiver muſt be filled with oxygen gas, and C with hydrogen gas. When the airs or gaſes are to be lighted, electric ſparks muſt be made to paſs from the end of the platina to the hole in a continual ſucceſſion; and while theſe ſparks are paſſing, the cock L muſt be opened by degrees till the air is ſeen to take fire; the electric ſparks muſt then ceaſe, and the ſize of the flame may be regulated by turning the cock either one way or the other. The other cock muſt then be ſet either quite open, or partly ſo, accordingly as you find the flame affected by it. As you find the gaſes decreaſe in the receivers, fill them by certain known meaſures, and continue the operation †.

SCIENTIFIC

* Communicated by George Pearſon, M.D. F.R.S. &c.

† The above deſcription was drawn up by Mr. Cuthbertſon. I find, upon examination of the apparatus at Dr. Pearſon's houſe, that the hole through which the hydrogen is introduced is made very ſmall, but that the other hole through

## SCIENTIFIC NEWS.

*Account of the Public Sitting of the National Institute of Sciences and Arts, held at Paris the 15th Messidor, in the Year VI. (July 3, 1798.)*

CITIZEN Bitaubé took the chair at half past five o'clock, the citizens Villars and Andrieux performing the office of secretaries. Citizen Villars ascended the tribune, and gave an account of the operations of the class during the last trimestre, of which the following is an abstract:

A memoir of Cit. Camus on the typographic art, polytipage, and the art of composing geographical charts, such as have been executed by the celebrated Haas at Basle.

A memoir of Cit. Langles on the Arabian poets who preceded Mahomet. This young and laborious student shewed that, even at a period so remote, the greater part of these writings possessed considerable poetical merit.

Cit. Monges read a memoir on the ruins of Persepolis, in which he proves that the destruction by Alexander was not total, but that it subsisted long afterwards.

Cit. Papon, associate correspondent of the class of moral and political sciences, read to the class of literature a memoir on the advantages which may be obtained from the study of Greek and Roman inscriptions, in order to ascertain a variety of historical facts.

Cit. Lefevre-Gineau gave a short account of the object of the various mathematical memoirs which had been read during the last trimestre.

A memoir of Cit. Lamarck concerning the action of the moon upon the atmosphere. It has been observed, that when this satellite is to the north of the equator, the winds blow, for the most part, from the north; and that they pass to the west or south-west, which in these climates are attended with rain, when the moon is to the south of the equator.

Cit. Flangaques, associate correspondent at Viviers, transmitted to the class a memoir on the refraction of light.

Cit. Leboffut communicated a memoir on the integral calculus, which, besides the perspicuous disposition of its parts, exhibits some original methods invented by the author.

A memoir of the laborious and indefatigable Messier, on the comet of the 23d Germinal, (April 12). The orbit of this comet, which, after having been seen for 43 days, disappeared in the constellation Ursa Major, has been calculated according to the method of Laplace. Fifty comets have already been observed by Messier, of which 21 were discovered by him.

Cit. Lassus, who was appointed to give an account of the memoirs on natural philosophy and chemistry, mentioned a memoir of Cit. Guyton on the affinities and the decomposition of salts at a temperature beneath the freezing point.

through which the oxygen passes is of considerable magnitude. I conclude that these dimensions of the apertures were ascertained by experiment, as the best suited to the complete though slow combustion of the hydrogen. As the bulk of hydrogen gas required to be introduced, for perfect combustion, is more than twice that of the oxygen, and the friction through the small aperture is very great, it becomes necessary that the pressure to extrude the former should be the strongest. The hole t renders it impossible to extrude the oxygen by the reaction of any longer column of water, than from that hole to the surface of the water in the tub; but the pressure which can be exerted in the vessel B is nearly twice as much. N.

Cit.

Cit. Clouet. aſſociate correſpondent at Ouzour, near Gien, tranſmitted a memoir to the claſs, deſcribing a method of converting iron into ſteel without cementation. He makes uſe of ſilex, alumine, &c.

Cit. Baumé, likewiſe aſſociate correſpondent, read to the claſs a memoir on the material of which artillery is made, and the cauſe of the degree of heat they acquire after a few diſcharges. He offers a new compoſition leſs ſuſceptible of becoming heated.

Cit. Gibert treated of fleece-bearing animals, or ſheep, and the advantages which commerce may derive from their produce. Lamarck gave an account of the cuttle fiſh; and Cit. Cuvier, of the internal diſpoſition of the throat of birds, by means of which they utter ſounds more or leſs acute. Cit. Deſeſſarts was the author of an excellent memoir on the ſmall-pox, with a ſhort account of Galvaniſm.

The claſs of mathematical and phyſical ſciences had propoſed as the ſubject of a prize, to be determined on the 15th Vendemiaire, in the year VII, (October 6, 1798) for which the productions of candidates were to be received until the firſt of Germinal laſt, (March 21, 1798) the following queſtion:

What are the uſes of the liver in the various claſſes of animals?

One memoir only has been received, which does not apply to the queſtion. The claſs has therefore thought proper to divide it, in order to facilitate the ſolution. In this form it becomes the object of two prizes. The queſtion for the firſt prize is,

To aſcertain the form, ſituation, magnitude, comparative weight, texture of the veſſels, communications, and appendices to the liver, conſidered in the principal claſſes of animals from man to inſects, molluſcæ, and worms.

The object of the ſecond prize is,

The analyſis of the hepatic or cyſtic bile in the ſeveral claſſes of animals here mentioned.

Memoirs will be received till the firſt Nivoſe, in the year VIII, (December 21, 1799) and the prize will be aſcertained on the 15th of Germinal following (April 4). The prize for each queſtion will be a medal of gold weighing one kilogramme (22966 grains, or 47 oz. 17 dwts. troy). The Inſtitute has publiſhed a program, exhibiting the conditions to which candidates muſt conform.

A prize was decreed. It was divided between two different works; but in effect it proved but one, becauſe the ſame perſon was entitled to both. In the year IV the claſs of mathematical and phyſical ſciences propoſed the following object:

To conſtruct a pocket watch proper to determine the longitude at ſea, by obſerving ſuch diviſions as indicate the decimal parts of the day, namely, tenths, thouſandths, and ten thouſandths; or the ſyſtem in which the day ſhall be divided into ten hours, the hour into one hundred minutes, and the minute into one hundred ſeconds.

The Inſtitute divided the prize between two watches, No. 1. bearing the epigraph "Ma "liberté fait ma conſtance;" and No. 2. having the inſcription "Au tems qui inſtruit."

Cit. Louis Berthout conſtructed both watches. His name was proclaimed amidſt the applauſes of the aſſiſtants.

The claſs of moral and political ſciences propoſed the two following queſtions, one relative to the ſocial ſcience, and the other to geography:

What ought to be the extent and the limits of power in the father of a family in a well-conſtituted republic?

The reception of memoirs will terminate on the 15th Meſſidor, in the year VII, (July 3, 1799) and the prize will be diſtributed the 15th Vendemiaire, in the year VIII (October 6, 1799).

To determine the great changes which have taken place in the globe of the earth, and are either indicated or proved by hiſtory.

The concurrence will ceaſe on the 15th Vendemiaire, in the year VIII, (October 6, 1799) and the prize will be diſtributed on the 15th Nivoſe following (January 4, 1800).

The ſame claſs had two prizes to diſtribute at this ſitting. One on the queſtion, 1. For what objects, and on what conditions, is it proper that a republican ſtate ſhould open a public loan? The other on this queſtion: 2. What are the inſtitutions moſt proper to eſtabliſh the morals of a people?

The memoirs tranſmitted not having complied with the conditions of the program, the Inſtitute propoſes again the queſtion reſpecting loans for the year VII. The concurrence will cloſe on the 7th Meſſidor (June 25, 1799), the prize will be given on the 15th Vendemiaire following (October 6, 1799); and the claſs of moral and political ſciences, at its next public ſitting, will give a new program for the development of the queſtion reſpecting inſtitutions. Among the memoirs which have been received, three are noticed as worthy of diſtinction, reſpectively bearing the epigraphs, 1. Si forte neceſſe eſt . . . fingere . . . non exaudita . . . contingent; dabiturque licentia ſumpta prudenter. 2. Nec enim ulla res vehementius rempublicam continet, quam fides. 3. On n'honore pas la vertu; on la reſpecte. The prize propoſed for theſe four queſtions will be a gold medal of the weight of five hectogrammes (11483 grains, or 23 oz. 18 dwts. troy).

Cit. Lacuée, ſecretary, in a ſhort account of the labours of his claſs, ſpoke of two memoirs of Cit. Deliſle-Deſalles, and another of Cit. Rœderer, all three concerning the government of China. It cannot be diſſembled, that it will always be very difficult in France to acquire a perfect knowledge of the government of a nation, of which the laws cannot be ſtudied in the country itſelf, or at leaſt in the writings of that people. Depending on the report of other writers, who themſelves may not have been perfectly informed, the two members of the Inſtitute have maintained different opinions, and each refers to his authorities. Cit. Deſalles affirms that this government is tyrannical, and brings facts in proof of this aſſertion. Cit. Rœderer, from the ſtability of the government, deduces a proof that its baſis is republican. He eſtabliſhes, with much acuteneſs, a difference between the patriarchal government, in which a ſingle chief influences the whole family, and the paternal government, in which the authority is divided into as many branches as there are married individuals. He likewiſe treats of the ſyſtem of the Chineſe writing.

Cit. Villeterque, aſſociate correſpondent, read a memoir ſomewhat abſtracted on the difference between experiment and reaſoning in philoſophy.

Cit. Goſſelin was mentioned as the author of another memoir, in which he has developed the geographical ſyſtem of Polybius. It is known that this expreſſion denotes the ideas which that hiſtorian entertained reſpecting the mathematical diviſions of the ſurface of the globe, and the ſituations of places. The ſame ſkilful geographer has before proved that Eratoſthenes, Strabo, and Ptolemy, had very incorrect notions of this ſcience.

Certain

Certain memoirs of Cit. Bouchad, on the legiflation of the Romans, and their numifmatic hiftory, were mentioned; and after thefe accounts the prefident fucceffively announced the readings.

Cit. Lefevre-Gineau read for Cit. David Leroy a memoir on the fhips of the ancients, in which he proves that we may derive ufeful inftruction from them. Cit. Delambre read a memoir on the meafure of a bafe taken in the neighbourhood of Melun, for determining the length of the meridian.

Cit. Fleurieu read a memoir on the civilization of the north-weft parts of America, where the traces are found of acquifitions which do not belong to nations abfolutely favage; fuch as ingenious conftructions, fculptures and indifferent paintings reprefenting animals, the parts of the human body, &c. He concludes that their anceftors fled to thefe countries from the ravages of the Spaniards during the conqueft of Mexico.

Cit. Chaptal read a memoir on the yellow colour obtained from vegetables.

Cit. Monges difcuffed the queftion, whether the two antique ftatues known by the names of the gladiator and the dying gladiator do really reprefent gladiators. He clearly eftablifhes the difference which exifted between the gladiators of the Romans and the athletics of the Greeks. The firft were barbarians, whofe lives were mercilefsly expofed; the fecond, Greeks, and fometimes heroes, who diftinguifhed themfelves by their ability in perfonal activity. The author does not believe that the ftatues in queftion are entitled to the denominations they bear.

Cit. Colin d'Harleville himfelf read a dialogue, entitled, "Man and his confcience," a very well written philofophical production. Cit. Lalande read a piece on the variation of the magnetic pole.

The fitting was terminated by Cit. Molé, who delivered a very happy tale written by Cit. Andrieux, entitled, The Dean of Badajoz.

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THE public attention has lately been much excited by a project of Mr. R. Dodd, engineer, for a communication between the counties of Kent and Effex, by a tunnel or fubterraneous road beneath the Thames, from Gravefend to Tilbury. The particulars as they appear in the newfpapers, inferted as I apprehend by the engineer himfelf, are as follow:

The tunnel is to be cylindrical, and lined on all fides with ftone keyed together in the manner of an arch; the internal diameter to be fixteen feet, which Mr. Dodd imagines will be fufficient for foot, horfe, and carriage paffengers. The paffage muft of courfe be illuminated with lamps, and a fteam-engine is propofed to be erected in a proper fituation to draw off the drainage water if any fhould accumulate. The eftimate is ftated as follows:

| | |
|---|---|
| To 900 yards (running meafure) of tunneling, includi[illegible] vaulting with key-ftones, &c. at 12l. per yard - - - | £. 10,800 |
| To relaying the bottom with new made ground 900 yards at 1l. each - | 900 |
| To placing lamps and lamp irons through the tunnel, collectors' rooms, and gates at each end - - - - - | 400 |
| To making good the entrance roads at each end of the tunnel - - | 160 |
| To a fteam-engine to draw off drainage water - - - | 1,780 |
| Neceffary machinery during the execution - - - | 500 |
| To ten per cent. upon the whole for contingencies - - - | 1,415 |
| Total | £. 15,955 |

I do not find, from the enquiries I have yet been able to make, that any effective ſteps have been taken towards carrying this plan into execution. It may, as Mr. D. obſerves, be done either at the expence of the two counties, or by a private ſharing company under an act of Parliament of the ſame tenor as is uſually obtained for canals. But whatever may be the mode, there can be no doubt of the very great commercial advantages of ſuch a communication. It would demand a greater degree of attention and reſearch into the circumſtances of local ſituation; ſuch as the depth and poſition of the main channel, the elevations of the banks, the nature of the ground, with the prices of materials and workmanſhip, than on the preſent occaſion can be thought of, to form any judgment of the eſtimate or the difficulties which may attend this important work. To the great public, Mr. Dodd's propoſal will appear intereſting in a more general point of view. When it is conſidered that the practice of making tunnels has now been known for a conſiderable number of years in this kingdom; that in many, if not moſt inſtances, a tunnel will be much cheaper, and full as ſafe, durable and convenient as a bridge; that the tunnel may be made (at leaſt in favourable circumſtances of the ground) in ſituations where a bridge would be impracticable, and will leave that moſt valuable deſideratum the clear navigation above unimpeded:—this happy thought of Mr. Dodd may be allowed to promiſe beneficial conſequences of the greateſt magnitude to the community.

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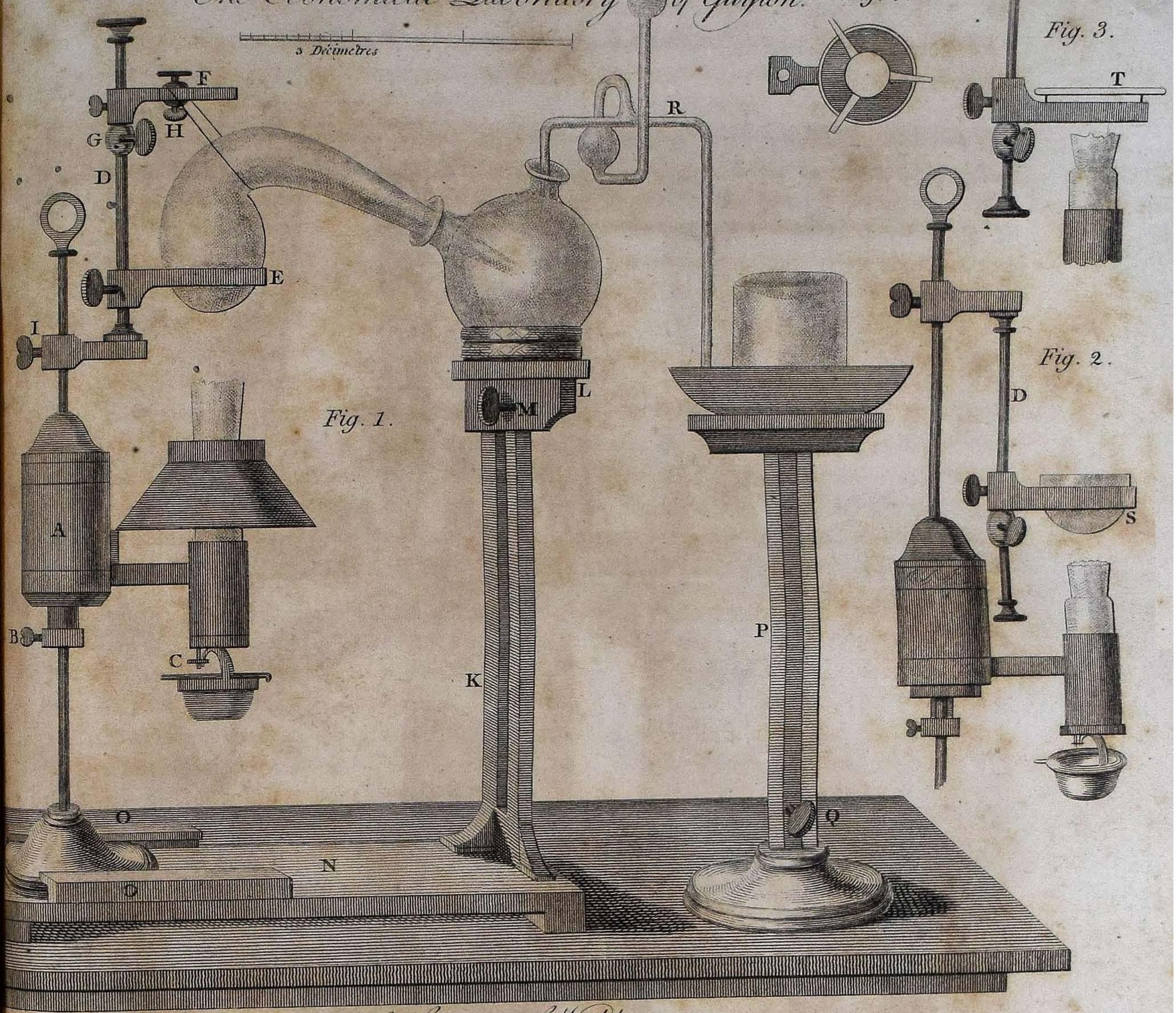
Dr. HERSCHEL has diſcovered four additional ſatellites of the Georgium Sidus. His paper on this object is inſerted in the late publication of the Royal Society *. By recurring to his former communication on this ſubject †, the two old ſatellites are found to revolve, the firſt in 8 days 17 h. 1 m. 17 ſec. at the diſtance of 33″ from its primary, and the ſecond in 13 d. 11 h. 5 m. 1,5 ſec. at the diſtance of 44″,23. The planes of their orbits form ſuch large angles with that of the planet itſelf, and conſequently to the ecliptic, as to be almoſt perpendicular to it. To this remarkable departure from the analogy of the old planets another ſtill more ſingular is now announced. *They move in a retrograde direction!* The new ſatellites revolve as follows, the periodical times being inferred from their greateſt elongations: The interior ſatellite in 5 d. 21 h. 25 m. at the diſtance of 25″,5.—A ſatellite intermediate between the two old ones in 10 d. 23 h. 4 m. at the diſtance of 38″,57.—The neareſt exterior ſatellite at about double the diſtance of the fartheſt old one, and conſequently its periodical time 38 d. 1 h. 49 m.—And the moſt diſtant ſatellite full four times as far from its primary as the old ſecond ſatellite. Whence it will take at leaſt 107 d. 16 h. 40 m. to complete its revolution. Whether the motions of theſe four be direct or retrograde, is, I ſuppoſe, not yet determined.

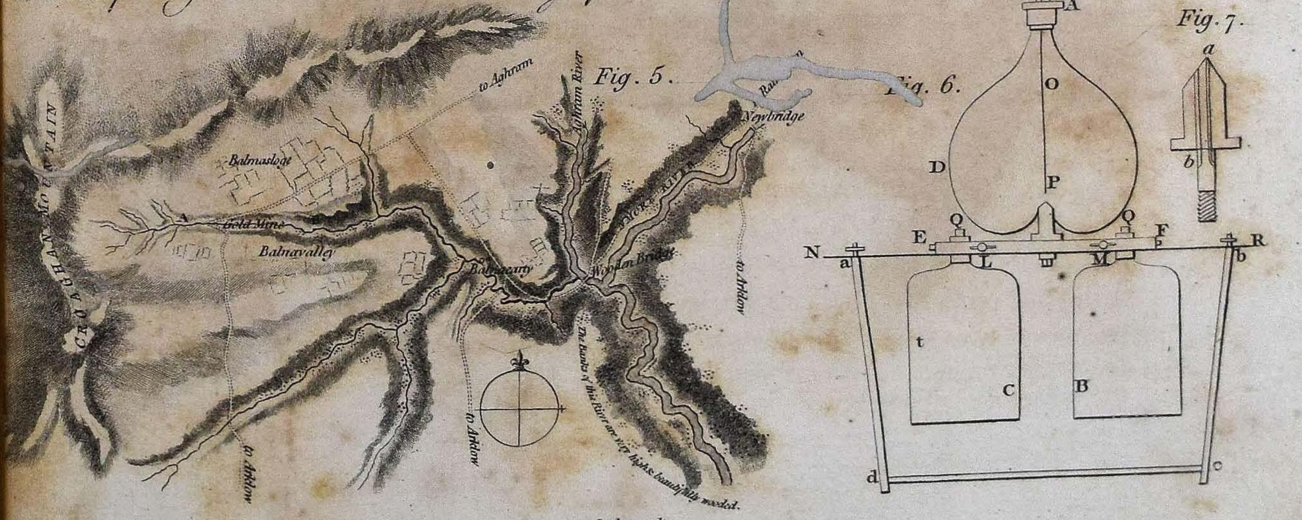
From ſome obſervations of the Doctor, with an excellent ſeven foot teleſcope, certain appearances reſembling that of two [illegible] ſurrounding the planet, and croſſing each other at right angles, were ſeen on ſeveral different days. They were not altered in poſition by turning the ſpeculum in its cell; but there is little doubt that they were optical deceptions, becauſe they kept their poſition with reſpect to the tube, after the relative poſition of the parallel had been much changed by the earth's rotation, and becauſe they did not appear with larger teleſcopes applied during the courſe of ten years. The diſk of the Georgium Sidus is flattened. It therefore revolves with conſiderable rapidity on its axis. From the very faint light of the ſatellites, they are obſerved to diſappear in thoſe parts of their orbits which bring them apparently neareſt the planet. This does not ariſe from an atmoſphere; for the effect is the ſame, whether the ſatellite be within or beyond the planet.

* Phil. Tranſ. 1798, p. 47. † Ibid. 1788.

## The Economical Laboratory of Guyton.

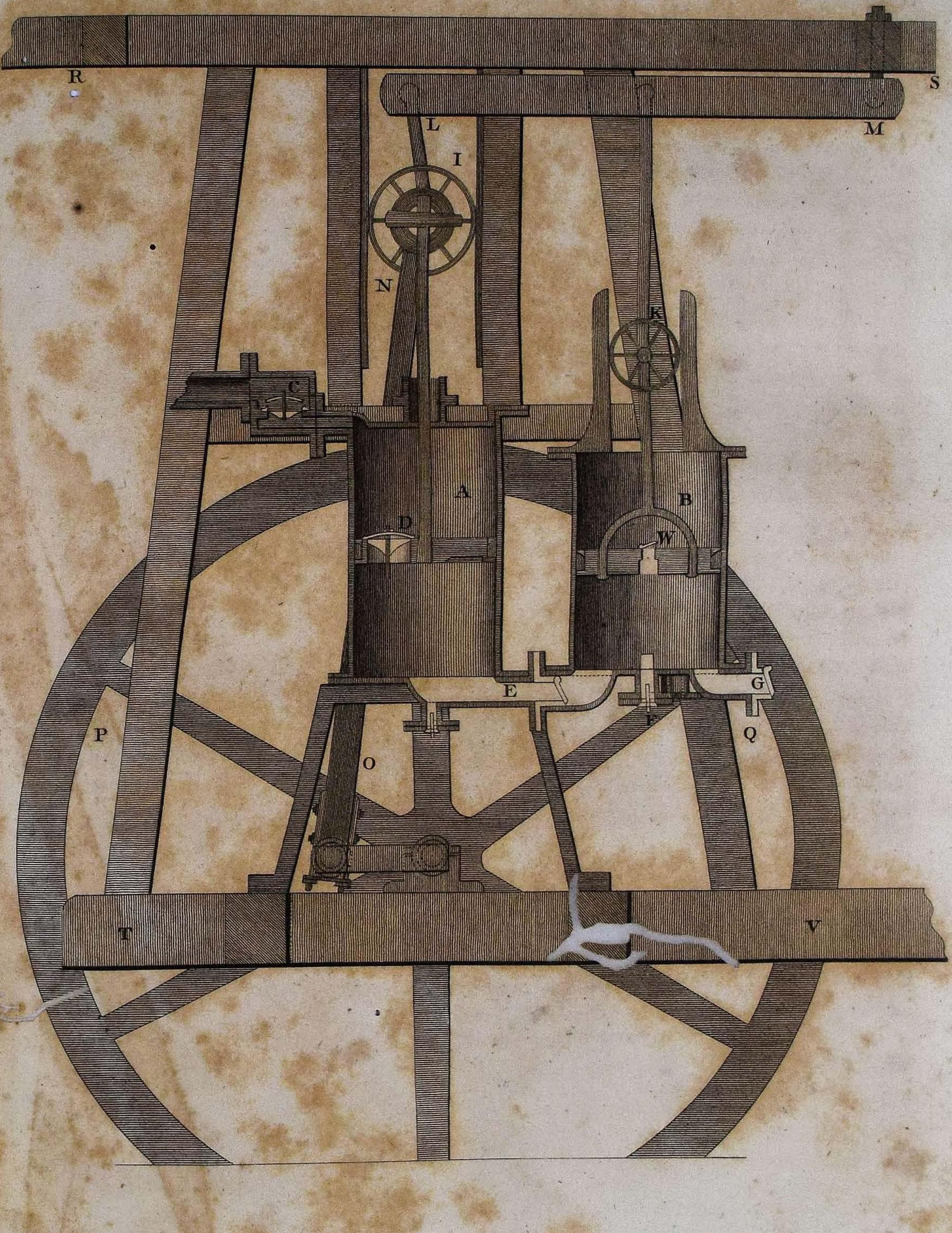



## Sketch of the Gold Mine in the County of Wicklow.




Barlow sculp

# Steam Engine by J. Sadler Esq.r




Barlow sculp.